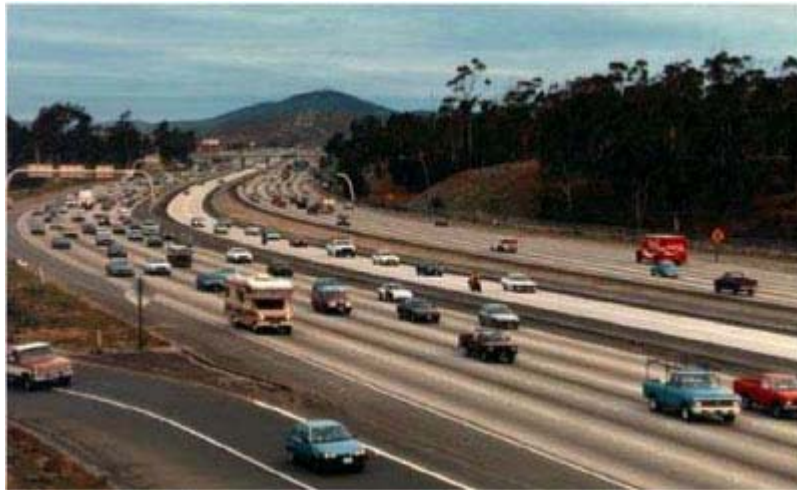


# **RFP DOT-2040 Section VI.C**



## **State of California Department of Transportation District 11**



### **I-15 Reversible Lane Control System (I-15 RLCS) System Requirements Specification – Version E**

**April 21, 2004**



### Modification History

After the baseline version of this document is approved, any new versions are noted here with the version letter and date. Any changes should be noted here, and referenced by an engineering change request number (ECR#).

Version	Date	ECR #s
A	Unknown	None
B	Unknown	None
C	December, 1998	None See Appendix C for a traceability matrix of changes between Version C and Version D.
D	June, 2002	Baseline version for procurement. Version D is to be used for procurement of development/ integration vendor services. Change control will go into effect for version E.
E	April 21, 2004	Final modifications prior to RFP release.



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## Introduction

This document defines the system requirements for the Interstate -15 Reversible Lane Control System (RLCS).

The RLCS will meet all and only the system requirements listed in this document, and if any changes are made to the original set of requirements, this document will be updated to reflect those changes upon approval of project management and the appropriate stakeholders.

### Requirements Working Group (RWG)

The I-15 Reversible Lane Control System RWG included members from various organizations within Department of Transportation District 11, as well as consultants from Visionary Integration Professionals (VIP). The RWG met periodically from May through December, 2001, in parallel with an effort to create a Feasibility Study Report for submission to the Department of Information Technology and the Department of Finance, Technology Investment Review Unit. The RWG reviewed the existing System Requirements Document – Version C, and determined which requirements should be kept and which were no longer valid, or better suited for inclusion with the Request for Proposals document. The list of stakeholders and consultants comprising the RWG is included in Appendix A.

In addition to stakeholder input, the RLCS requirements were gathered or derived from the following sources:

- User Requirements Document,
- Existing Systems Documentation,
- Requirements Analysis

### **1.1. Purpose (of document)**

This document has three purposes:

First, it identifies all stakeholder and top level technical requirements for the RLCS. This document will serve as the communications vehicle for the clear understanding of these requirements for both the stakeholders of the system and the implementers of the upgraded system. This document is a WHAT document not a HOW document. This means that WHAT the system is to do will be contained in this document and HOW these requirements will be implemented will be contained in design documents developed by the vendor.

This System Requirements Specification document serves as the basis for the Software Requirements Specification, and for all non-software designs for the RLCS. (The Software Requirements Specification serves as the basis for the software design.) The traceability matrix included in the appendix of this document will be maintained and ensure a clear history of changes from the prior version of this document.

Finally, this document is intended to contain all the system requirements throughout the life of the project. It is the intent of this document to assist in the management of these changes in an orderly manner through baseline and version control.

## 1.2. System Goals

The new system will realize the following objectives:

1. Adapt to changes in field devices as necessary to integrate the I-15 construction projects.
2. Minimize or eliminate the programming required to add or modify field devices, relationships and protocols by using a high-level software environment. New or modified devices should be accessible to the system without programming changes, for inclusion in all system data representations, including the graphical user interface, system log files and data stores, field device lists, and reports.
3. Provide RLCS status to outside systems via an external server data store. The status will consist of a simple message set as an ASCII file, updated at a configurable frequency.
4. Capture and report on RLCS program and management information including operations logs, incident reports, system availability, and other information based on operational data
5. Analyze performance events such as recurrent device failures, escalation and communication protocols, and other PIER data, against established benchmarks for continuous improvement opportunities.
6. Share information with other regional intelligent transportation systems. FasTrak and RMIS will receive reversible lane status information to better manage their controls and signage. ATMS and ATIS will receive reversible lane status information to assist in regional traffic management, incident detection and response, and to inform the public about traffic conditions.
7. Permit the lanes to be opened/closed more quickly and flexibly than the current system allows, thereby making the system more responsive, in both daily operations and incident management.
8. Replace unmaintainable field device controllers and associated interface cards with current technology. The existing device controllers lack spare parts and replacements are no longer commercially available.
9. Provide system diagnostic functions down to the field device sensors. To facilitate troubleshooting, the system diagnostics functions should monitor the devices periodically, and report status conditions intelligently.
10. Use modern software architecture, and support system configuration and programming using high-level languages and graphical representations, to reduce the need to perform software program modifications for system administration functions. Eliminate EPROM upgrades in the field for routine maintenance of the system.
11. Maintain the stand-alone environment of the I-15 RLCS. Provide appropriate security to allow RLCS access only to authorized personnel



12. Provide emergency response information to system users to respond to field device failures more efficiently.
13. Facilitate the operations process by employing a Graphical User Interface and automated command sequence execution.
14. Improve system reliability through improved hardware, software, management, scheduling, and coordination with maintenance in the areas of troubleshooting and preventive maintenance.
15. Improve the administration of the RLCS including security, report generation, and system configuration.
16. Provide a simulation environment for testing hardware and software changes, and for conducting training, which cannot be performed in the production environment due to public and employee safety considerations.

### 1.3. Definitions, acronyms, and abbreviations

See Appendix B for a table of terms used in this document.

### 1.4. References

The documents used as reference for preparing the requirements are listed in Table 1.

Title	Prepared By	Date
Software Engineering Economics	Barry Boehm	1981
I-15 Reversible Lane Control System Existing Control System Report *	Caltrans	9/1998
I-15 Reversible Lane Control System System Requirements Document – Version C	Caltrans	12/1998
I-15 Reversible Lane Control Systems Project – User Requirements Document – Version D	Caltrans	12/1998
IEEE Guide for Developing System Requirements Specifications 1233-1998	IEEE	12/1998

\*Available [on](#) the Project CD-ROM

**Table 1 – Reference Documents**



### **1.5. Overview (of document)**

The remaining sections of this document are described below:

Section 2 gives a general system description including the context for the system, its modes and states, capabilities, conditions, constraints, user characteristics, and operational scenarios.

Section 3 is the requirements section. All capabilities, conditions, and constraints on the system are given in detail, including interface, physical, performance, security, information management, operations, policy and regulation, and system life cycle maintenance.

Appendices contain supplemental material referenced within the body of the document.

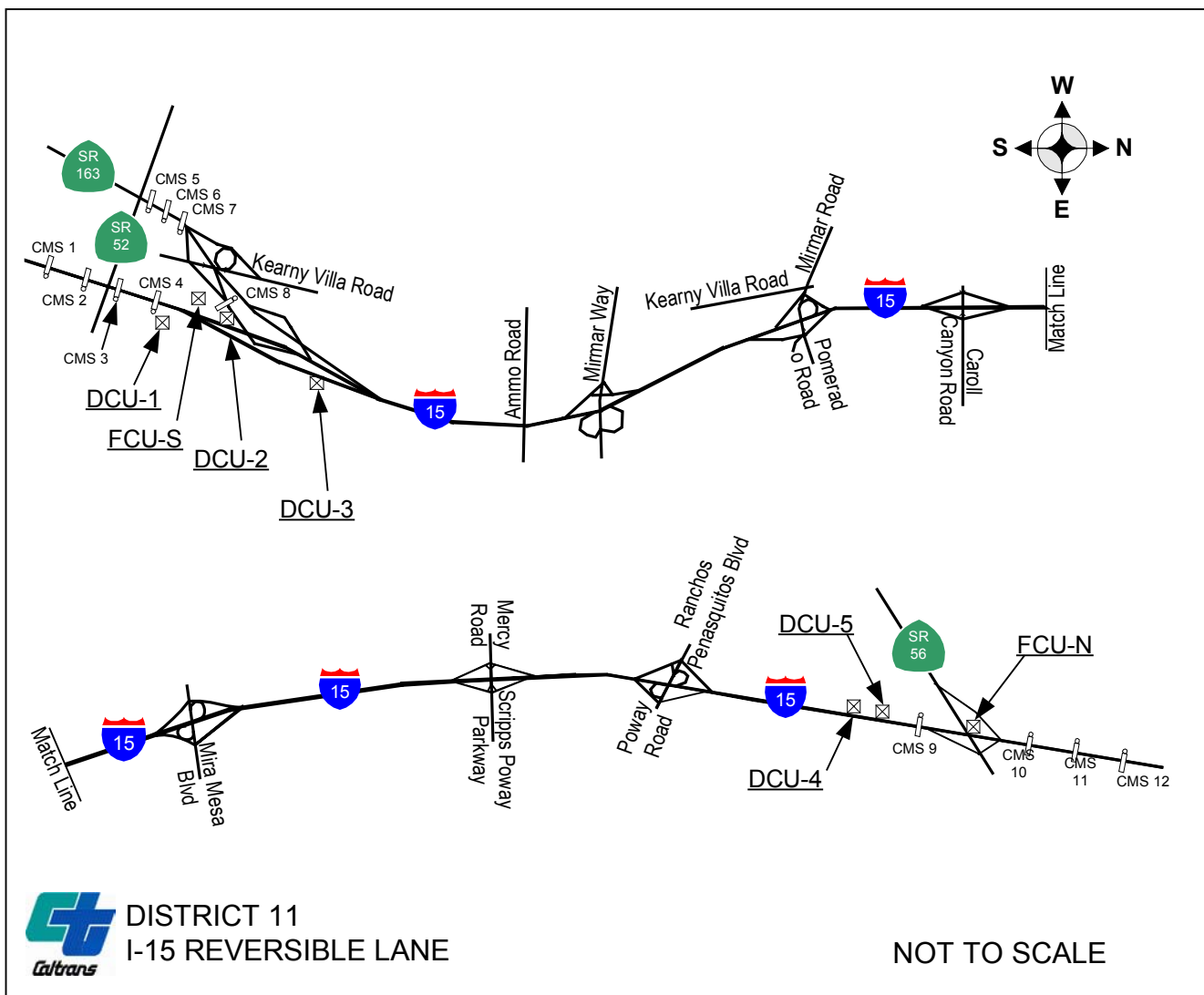
## 2. General System Description

This section describes the general factors that affect the system requirements. This section does not state specific requirements; instead, it provides a background for those requirements, which are defined in detail in Section 3.

### 2.0.1 Environmental Description

The map below shows the geographic layout of the I-15 RLCS facility, including the two Field Control Unit (FCU) buildings at the South and North ends of the facility (FCU-S and FCU-N), and the five locations where Device Controller Units (DCU) are currently installed in the field (LOC #1-5 represent DCUs 1-5). These locations will not be changed, and the proposed RLCS will need to function in this physical environment.

In addition to the field environment, the proposed RLCS will be installed in a simulated environment at the TMC.



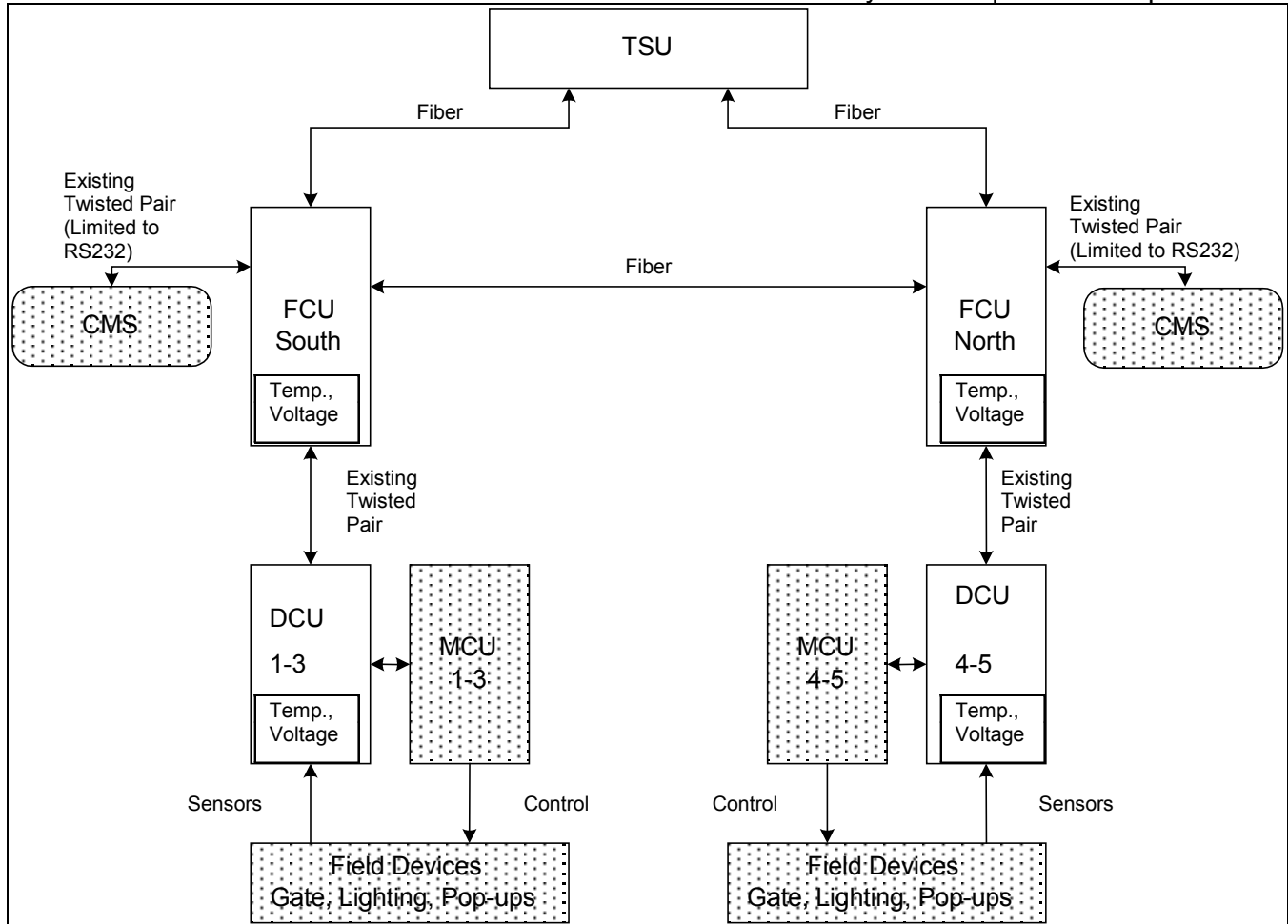
**Exhibit 2.1: Location Map**



### **2.0.2 Architectural Description**

The current configuration is a 3 tier hierarchical architecture of controllers, where tier 1 is the TSU (Traffic Systems Unit), tier 2 is the FCU (Field Control Unit), and tier 3 is the DCU/MCU (Device Control Unit/Manual Control Unit). The proposed system will maintain this hierarchy, plus, add the ability for each FCU to act as the tier 1 controller in the event that the TSU is not functioning.





**Exhibit 2.2: Proposed RLCS Architectural Hierarchy and External Field Devices (shaded items)**

Note: The shaded items are external field devices outside the proposed RLCS, but within the RLCS Facility.

**TSU** - The TSU is the main communication node for the RLCS. Its function is to provide communications between the terminal operator in the TMC and the field devices through the FCUs at the north and south ends of the facility

**FCU** - The FCU controls DCUs, CMS and monitors the air supply system within its respective communications network. The FCU serves two main functions in the I-15 Reversible Lane system of field elements. It monitors the status of a number of devices in the FCU building, including air pressure, and street lighting status, and it translates commands from TSU to monitor and control field devices.

The FCU receives command and control information from either the TMC or from a computer terminal attached to the FCU. The primary communication between the FCU and TSU will be over a fiber

network and the secondary communication will be over leased lines. Dial up telephone lines will be used to connect to the FCUs in the event of communication loss with the TSU. The heart of the FCU is a VME based computer with unique system software. The VME based computer is comprised of various plug-in cards. The FCU monitors and controls field devices at each location through respective DCUs



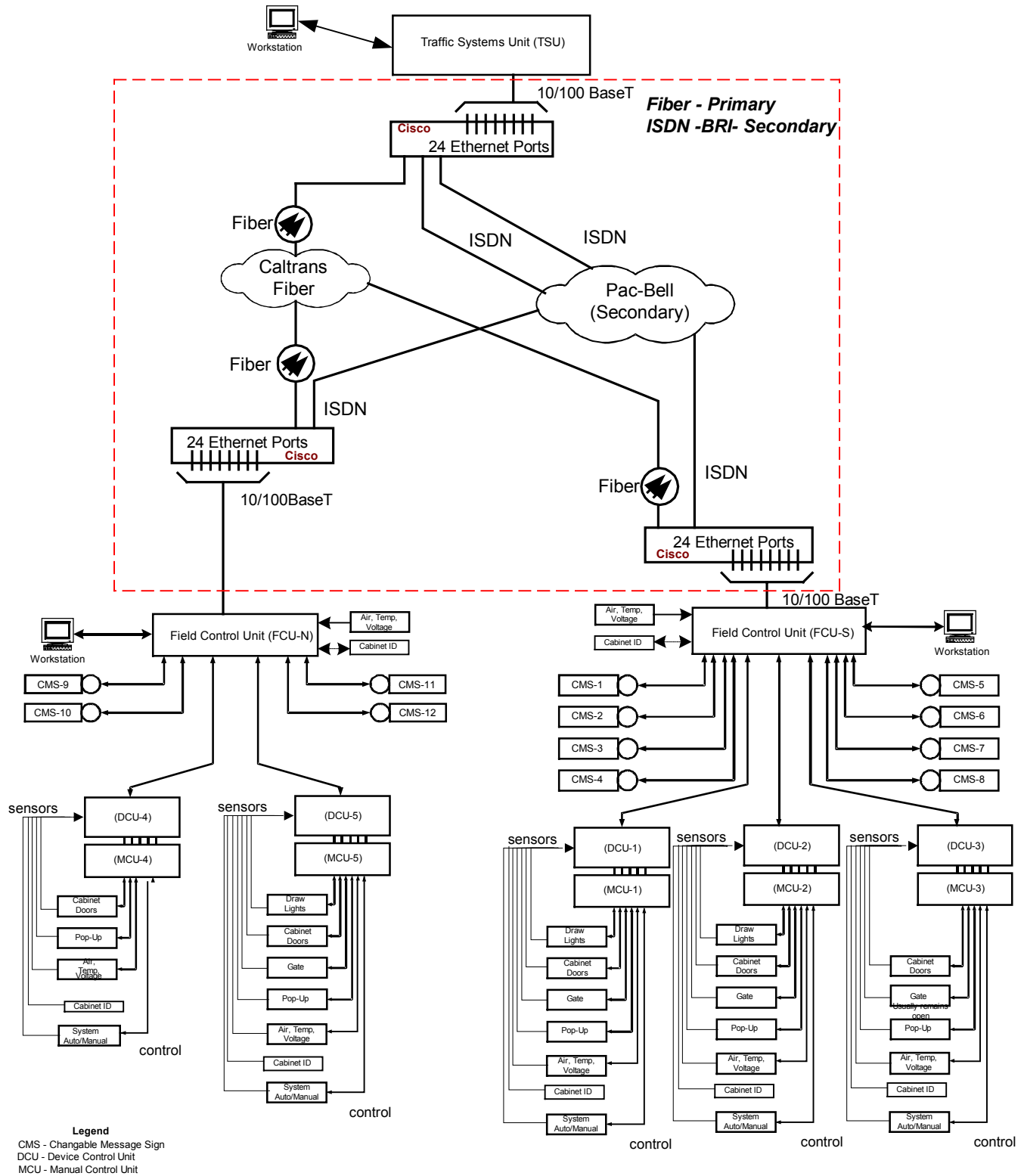
**DCU** - The DCU controls pop-ups, gates (where applicable), and provides real-time status information to the TSU through the FCU interfaces. The DCU/MCU control system at each of the five field locations serves several functions. The MCU is the power supply for the DCU as well as the pop-up system and gate system where applicable. The DCU provides 120 volts of AC to activate solenoid valves, which controls the flow of compressed air to raise or lower the pop-up tubes. The DCU provides local command and control of the field devices at each location. The heart of the DCU control system is the VME system similar to the one used in the TSU and FCU. The DCU receives sensor inputs from the pop-up sensors, the air pressure sensors at the local air tank, and the gate sensors.

**MCU** – The MCU supplies power to the DCU as well as to the pop-up system and gate system. Power is delivered to the MCU at 480 volts and is stepped down to 120 volts. Other field devices, the gate system, the warning lights and the interchange lighting (draw lights) are powered from the MCU. The DCU main power switch is located on the front panel of the MCU, and is used to disconnect power to the DCU. The power to the draw lights is also controlled from the MCU. The Gate and gate warning light power is isolated from the DCU and MCU by five relays located in the gate control cabinet. The MCU provides Auto / Manual control capability for the pop-up system and gate system (where applicable) and all other devices at each location. When in manual mode, the DCU control of the field devices is transferred to the MCU. The MCU contains switches which bypass the outputs of the DCU and provide the needed impulse power directly to the field devices.



I-15 RLCS System Requirements Specification

The following network diagram shows the multiple communications networks supporting the RLCS: fiber, leased lines, and dial-up lines. The communication between the FCU and DCU controllers is limited to serial connections.



NOTES:  
1) DCU controls devices through the MCU (set to 'auto' mode).  
Sensors interface directly to DCU.  
2) FCU to DCU communications is serial only.

**Exhibit 2.3: Proposed RLCS Network Connectivity**

### **2.0.3 Proposed RLCS Improvements**

The proposed RLCS will operate within the existing architecture and keep its strengths such as processing redundancy, but will improve on weak areas such as the user interface, aging and obsolete hardware and difficult to maintain controller hardware and software.

New device controllers and field device interface cards will be installed as part of the proposed RLCS.

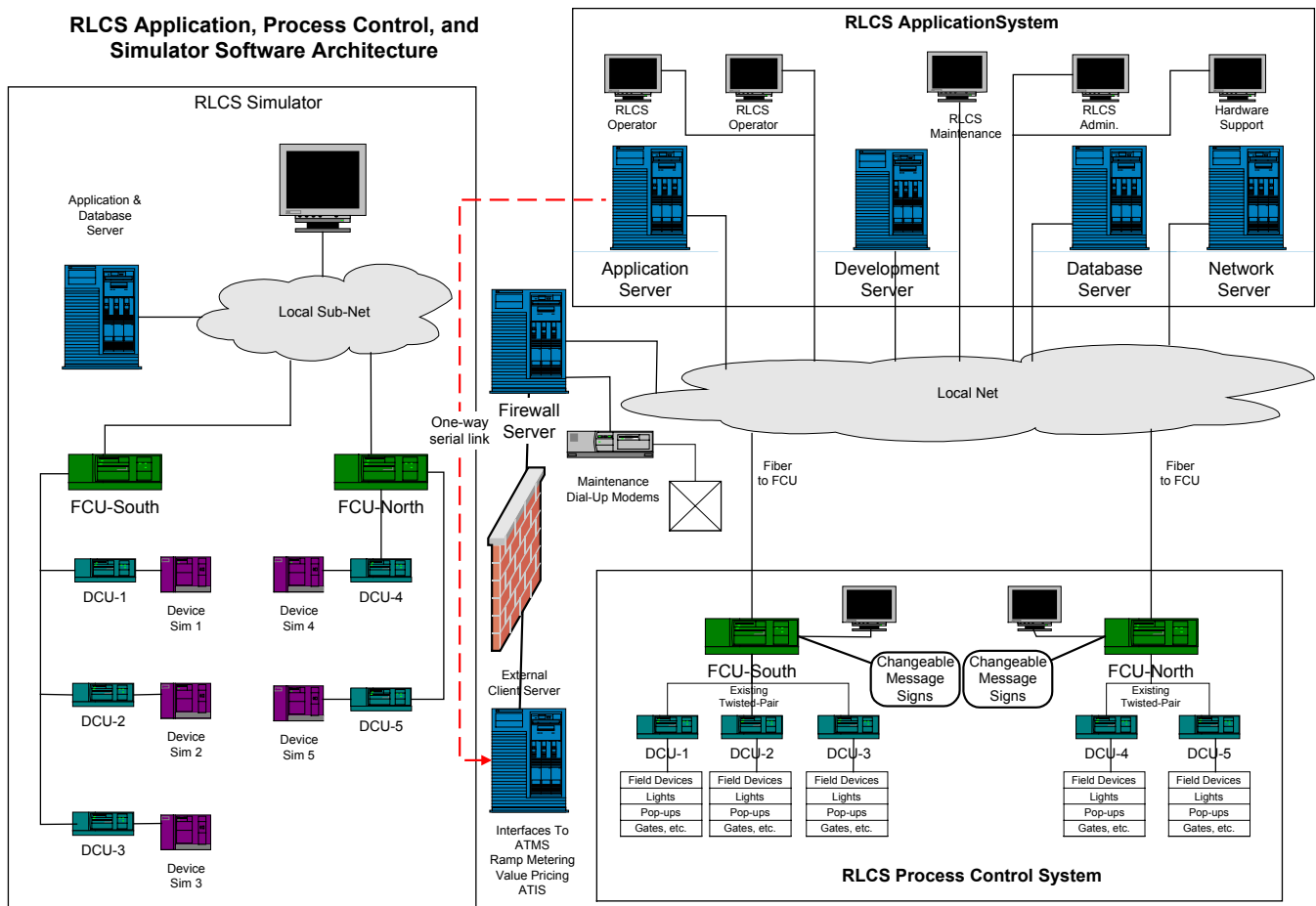
The technical requirements are based on the existing architecture, but the proposed RLCS shall accommodate expansion to include additional field control devices as required to integrate current and future I-15 Transportation Projects. For details about the device interfaces with the FCU and DCU controllers, see Appendix D.

Some of the requirements will be implemented in software residing on the new device controller hardware in the field, whereas other requirements will be implemented in application, database and network servers, and client hardware and software.

The diagram below also depicts the simulator environment, as well as an external server data store to provide RLCS status data to outside systems. Not shown in the diagram are dial-up lines connected to the FCUs which will be used in the event of communication loss with the TSU.

The conceptual configuration for the I-15 RLCS shown in Exhibit 2.4 includes the following components:

- Application (Control) Server hosts the application programs for the RLCS
- Database Server hosts the relational database
- Workstations
- RLCS Operator
- Maintenance
- Firewall processors segregate external system interfaces and the Simulator
- Simulator is a separate and independent version of the RLCS, including an application server, and FCU and DCU controllers connected to a device emulator. DCUs 6 through 10 do not exist in the field, but are part of the simulator in order to test the system expandability. These DCUs contain the same device configuration as DCU number 1. CMSs 13 through 16 do not exist in the current system but will be part of the simulator in order to test future system expandability. These CMSs will be connected to FCU-N. We shall be testing the ability and the ease of adding future control devices to the system.
- Device emulator is an electronic black box to emulate responses from field devices
- FCU Hardware includes upgraded controllers and workstations at the North, South, and Simulator locations. Hardware in the different FCU locations will work interchangeably.
- DCU Hardware includes upgraded controllers. The DCUs will maintain the existing interface to the field devices, with NO field device upgrades planned. New hardware in the different DCU locations will work interchangeably.
- Remote Access Laptops will be provided to allow support personnel access from remote or off-site locations.
- Communications between the TMC workstations and servers and the FCU controllers will use the Fiber Optic Network, with leased lines as back ups.



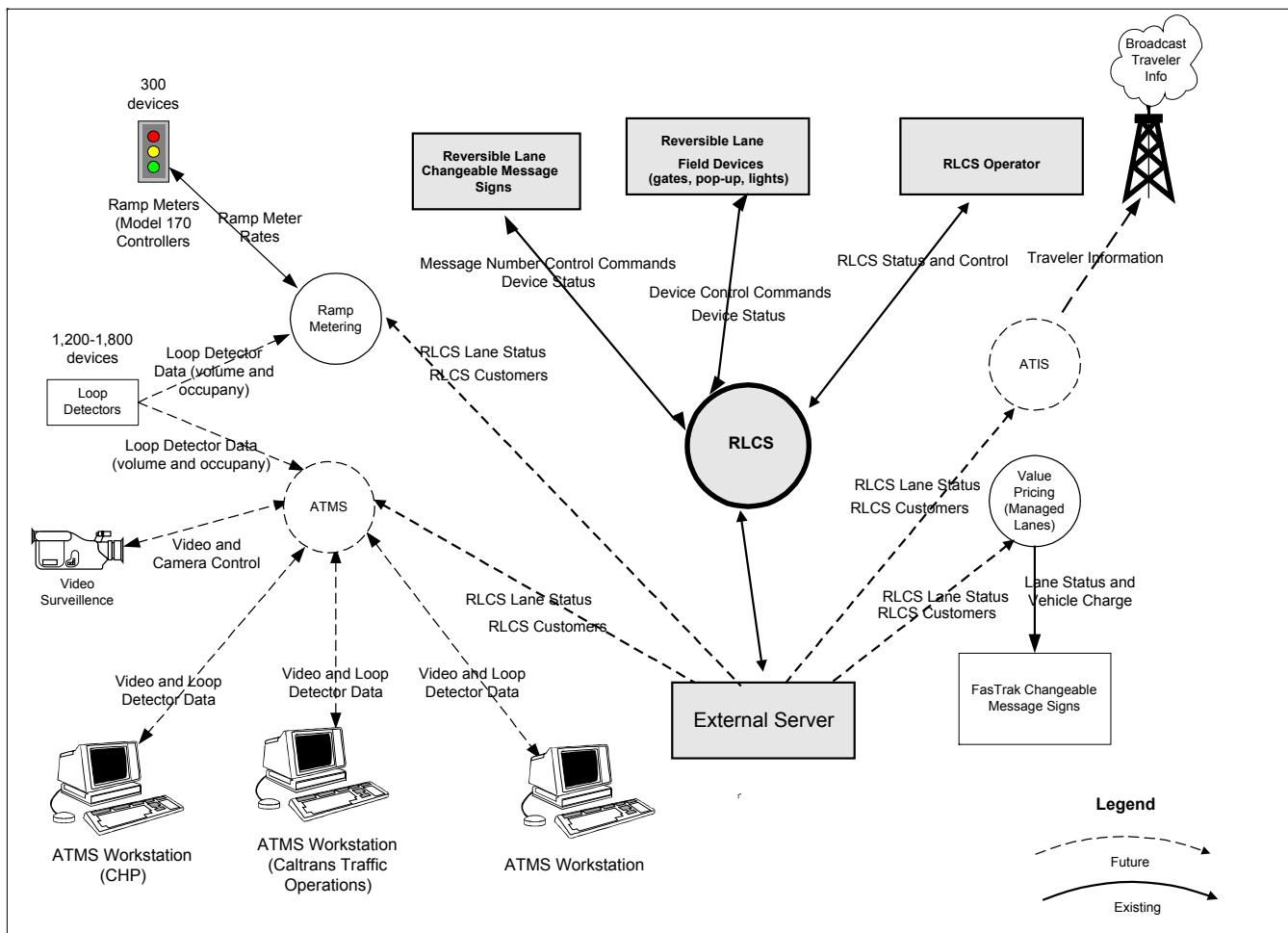
**Exhibit 2.4: I-15 RLCS Conceptual Configuration**

## 2.1 System Context

This section describes how the RLCS relates to other external systems, and to the field devices under its control and monitoring.

### 2.1.1. External RLCS Interfaces

The RLCS shall provide status data to other external systems via an external server data store accessible by other external systems such as ATMS-2, ValuePricing/FasTrak, and ATIS. **Exhibit 2.5** shows the flow of information to the different interfacing systems. (The circles represent the interfacing systems.)



**Exhibit 2.5: Proposed External RLCS Interfaces**

### 2.1.2. User Interface

The user shall operate the RLCS from a workstation or laptop computer through a graphical user interface.

### 2.1.3. Hardware Interfaces

The RLCS hardware interfaces consist of the following field device elements:

1. CMS - Changeable Message Signs
2. Gate Control
3. Pop-ups (Air Pressure)
4. Lighting
5. System Communications
6. System Power
7. Loop Detectors

These field elements are interconnected by about five miles of air lines and sensor lines; over ten miles of conduit for 480 volt power lines and ten miles of conduit for communication.

**1. CMS** - The reversible lane facility has a total of 12 Changeable Message Signs (CMS). CMS 1 through 8 are located south of the I-15 Reversible Lane facility entrance on I-15 and SR-163. CMS 9 through 12 are located north of the I-15 Reversible Lane facility entrance on I-15. They provide I-15 Reversible Lane facility users information on the status of the facility. (The CMS informs the motoring public whether the facility is open or closed.)

**2. Gate Control** - The facility has three operational gates. These devices are used to block reversible lane entrances when vehicles are using the facility in the opposite direction. The gates control mechanism has a number of built-in safety features to prevent malfunction. For the gate down operation, 'Power Enable' optically isolated switch (OIS) is first activated by issuing an active low pulse and the 'Gate Down' OIS is activated by issuing an active high pulse. When the gate reaches a 15 degree position, it returns a 'Gate 15Deg.' sensor signal, the built-in safety feature then reverses the polarity of the issued pulses, such that the 'Power Enable' OIS is now issued an active high pulse and the 'Gate Down' OIS is issued an active low pulse. Once this bit reversal happens the gate will continue the Gate Down operation, till the gate arm is securely latched and a 'Gate Locked' sensor is returned. If due to any reason this bit reversal does not happen then the gate does not continue any further beyond the 15 degree position. The gate can be manually operated from the MCU if power is available and the DCU is down. If the gate has no power, it can be manually cranked from the gate cabinet.

**3a. Pop-ups** - Pop-Ups are traffic delineators mounted on pneumatic pistons, which can be raised or lowered, to block the reversible lanes. The pop-ups are powered by compressed air and controlled by solenoid switches. The pop-ups are designated as entrance longitudinal (EL), entrance transverse (ET), wrong-way longitudinal (WL), or wrong-way transverse (WT), depending on the layout of the roadway. The positions of the pop-ups are monitored by their respective DCUs.

**3b. Air Pressure System** - Pop-ups are powered by an air pressure system. Each FCU contains an air compressor, a dryer, a cooler and an air tank. A metal pipeline based air distribution system delivers the compressed air to each MCU air tank, for delivery to the pop-ups. The air pressure systems at the FCU are controlled and monitored by the FCU, and the systems at the MCU are monitored by the DCU.

**4. Lighting** - Lighting is installed in all the entrances and wrong way areas to illuminate the areas while the lanes are open. The lighting at selected locations is controlled from the DCU.



**5. System Communications** - Communications between the field devices and control elements is achieved through various systems. Existing data and control functions are transmitted over analog leased lines to the two FCU locations. This system provides communications to all field elements, except the video cameras. The data lines from each FCU are connected to various punch down blocks, located in the TMC communications room, before connecting to the TSU. Data is transmitted between field systems and CMS through buried twisted pair cable; between FCU and DCU, and FCU and CMS. FCU South communications systems are the same as FCU North, with additional CMS. DCU communications are provided entirely through buried cable to field devices, as well as to the FCU. In the proposed RLCS, primary communications will be via a fiber optic network with leased lines as a backup. Dial-up lines connected to the FCUs will be used in the event of communication loss with the TSU to open and close the lanes.

**6. System Power** - Power to all the systems is obtained from a 480 VAC power source at the FCU. Power is received from a commercial power source at the FCU, and it is distributed to the various field units. Each field unit is equipped with a step down transformer that transforms the voltage to the appropriate voltage levels. Back-up power generators are on standby and are located in both the North and South FCU control buildings.

**7. Loop Detectors** – The Reversible Lane system was equipped with a number of traffic detector loops. The installations were intended to provide sensor information for the opening and closing operations. The loops were intended to assist in identifying gaps in the traffic stream to enable efficient closure of the lanes. Loops were also placed after the gates to detect errant vehicles in the lanes after gate closure.

#### 2.1.4. Software Interfaces

The RLCS will interface with an external computer to update the external data store with RLCS Lane Status data as described in External RLCS Interfaces.

#### 2.1.5. Communications Interfaces

There are two external communications interfaces with the RLCS.

The first is a one-way connection to the external data store outside the RLCS via a firewall to enable update of RLCS lane status data. Alternatively, should the firewall not be in operation, a one way serial link would be used to transfer system status.

The second consists of the remote dial-in interface through a firewall via a dial-up modem. This is a two-way interface that allows connection into the RLCS network via a remote computer equipped with the application software, and with a user logon authorized for remote access.

There will be no other external communications interfaces, including wireless connections between the FCU and DCU controllers, due to security and interference considerations.

The communication software will be required to interface with different media. The required media is single mode fiber and twisted pair copper (2 pair, each wire is AWG 18). For network communication the type of media shall be transparent to the software. 10/100 Base T and 10/100 Base FL Ethernet will be available where network communication is required.

Where network communication is required it shall be implemented using industry standard TCP/IP protocols.



Where serial communication is required it shall be implemented using industry standard protocol (either RS232 or RS422) compatible with each field device.

#### 2.1.6. Memory constraints

There are no constraints on system memory other than the constraints of the individual system components.

#### 2.1.7. Bandwidth Constraints

The RLCS shall communicate internally via the private communications networks established and maintained by the Department of Transportation within the following bandwidth constraints:

Between the TSU servers: 10/100 Mbit/s Ethernet

Between The TSU and the FCUs: 10/100 Mbit/s Ethernet

Between the FCU and the DCU: full duplex 9600 b/s serial at a minimum, but a higher baud rate is preferred if achievable with the existing wiring.

Between the FCU and the CMS controllers: full duplex 9600 b/s serial at a minimum, but a higher baud rate is preferred if achievable with the existing wiring.

### 2.2 RLCS Modes and States

The RLCS has two states: 'Open' or 'Closed'.

The RLCS shall allow operations to be performed in one mode at a time: Normal, Emergency, and Maintenance. These modes shall be defined in a database, allowing for flexibility in the number and types of RLCS operating modes. At a minimum, the RLCS shall support normal, emergency, and maintenance modes.

#### 2.2.1. Normal Mode

In this mode the RLCS shall allow the opening and closing operation sequences on a daily scheduled basis depending on peak traffic flow. The sequence of operations is predefined and regular.

#### 2.2.2. Emergency Mode

In this mode the RLCS shall allow operations to open and/or close the lanes in an alternative sequence, in response to a highway incident. This may include the need to reverse the direction of traffic flow by performing a close and immediately reopening in the opposite direction when safe.

#### 2.2.3. Maintenance Mode

In this mode the RLCS shall allow the user to perform operations for trouble-shooting and testing of field devices, on a scheduled and ad hoc basis.

### **2.3. Major RLCS Capabilities**

The RLCS shall provide the major capabilities outlined in this section. A combination of hardware and software shall interface to existing and additional field devices as they are needed in the future. The current physical location of the device control units (DCUs) and the North and South field control units (FCUs), as well as the existing air supply lines and serial communications lines, will constrain the physical architecture of the proposed RLCS.

#### **2.3.1. Application Software Capabilities**

The application software allows an operator to view system status and issue commands to change device status as well as configure the system and generate reports. The five major functions of the RLCS application software are a Graphical User Interface (GUI), Process Control and Monitoring, Sequencing, Data Processing and Security, and Reporting.

#### **2.3.2. Controller Hardware and System Software Capabilities**

**2.3.2.1 Hardware:** The current Transportation Electrical Equipment Specification (TEES) for the 2070 Advanced Transportation Controller (ATC) defines the minimum functionality required for the controller hardware component of the RLCS. Other controllers having the same functional capabilities as the 2070 ATC are not excluded from consideration for use in this RLCS, but must be tested by Department of Transportation for compliance, at a minimum, with the 2070 standard. See Appendix E for information on where to locate this standard in electronic form.

**2.3.2.2 Controller Operating System Software:** The operating system software should include a user interface and diagnostic software programs to enable the user to execute diagnostic programs to display the controller, I/O card, and field device statuses down to the sensor level. The user interface, at minimum, should be a text-based command line. The user interface should be accessible by interfacing a lap top computer directly through a serial or Ethernet connection and in addition, through a display device built into the controller.

**2.3.2.3 Controller Device Driver Software:** Device driver software will interface with the controller operating system software and provide the interface to the field device I/O cards which in turn interface with the field device sensors.

#### **2.3.3. Non-Controller Hardware and System Software Capabilities**

All non-controller hardware such as application server, database server, and network servers, workstations and laptop computers, as well as printers, interface cards, and other peripheral devices will not have any specialized functionality beyond the functionality available in general purpose, commercially available hardware, operating systems, and system utilities. The hardware and associated system software functionality must support the RLCS system requirements.

#### **2.3.4. Communications Capabilities**

**2.3.4.1.** The RLCS will incorporate the existing telecommunications network connections to accomplish communications between hardware and software components of the RLCS. The Department of Transportation will maintain the communication lines to adequately support the RLCS system requirements.

**2.3.4.2.** Valid checksum algorithms must be employed to check the integrity of messages between units.



### 2.3.5. Device Emulator Capabilities

Hardware and/or software to emulate each type of field device input and output will be used in the simulator environment only.



## 2.4. Major RLCS Conditions

### 2.4.1. Political

The current political conditions with regard to HOV lanes is that some public officials and members of the motoring public perceive that in many cases carpooling is an impossibility due to work and school schedules. In some parts of the State, and in the State legislature, there has been discussion about closing HOV lanes. Additionally, some public officials and members of the motoring public believe that only the affluent can afford to purchase FasTrak passes to use the lanes when traffic is heavy.

At the time these requirements were established, Department of Transportation District 11 continued to operate the I-15 HOV lanes in their current configuration, and had not received any indication that the operations would change in the foreseeable future.

### 2.4.2. Market

The RLCS will not be marketed to external customers, so the RLCS system requirements are not dependent on market conditions.

However, market conditions as they affect system integration vendors and the availability of vendors capable of building and integrating the RLCS will determine the final set of requirements. A Request for Information (RFI) was conducted in June, 2001, to determine the state of the industry's expertise in building a RLCS.

### 2.4.3. Standards and Technical Policies

The Transportation Electrical Equipment Specification (TEES) for the 2070 Advanced Transportation Controller (ATC) is the approved controller standard for the Department of Transportation.

Department of Transportation Information Technology standards are evolving, and will most likely not dictate operating systems or network standards for the RLCS. The RLCS will interface with Department of Transportation telecommunications networks, but will remain a separate system on the network.

National and regional standards for intelligent transportation systems are still evolving, but as a rule, RLCS standards for display colors or exported data formats should be adaptable to evolving standards of higher operating authorities such as SANDAG (San Diego Area Governments) and the Federal Highway Administration (FHWA).

Cabinet wiring and cabling must be in accordance with the TIA/EIA standards.

### 2.4.4. Cultural

There are no cultural considerations for the RLCS.

### 2.4.5. Organizational

Department of Transportation District 11 organizational conditions include a shortage of internal staff to implement the RLCS. An outside vendor will be sought through a Request for Proposals process (RFP), to build and integrate the system.

### 2.4.6. Physical

The physical configuration of the freeway lanes, and the reversing of the flow of traffic presents serious safety issues for the motoring public. ***The RLCS must always operate correctly to avoid the catastrophic situation where the lanes would be open to traffic in both directions, simultaneously. See section 3 for additional details.***

Due to its outdoor location near the I-15 and state route 163 freeways, the RLCS exposes Department of Transportation personnel to freeway traffic when they service the RLCS on-site for any reason. Minimizing on-site maintenance to minimize exposure of Department of Transportation personnel to freeway traffic is another top priority and condition for operation.

The RLCS physical devices are exposed to the outdoor environment, and the DCU controllers reside in cabinets also in the outdoor environment. All electronic components must therefore be able to withstand variations in temperature and moisture specified by TEES in order to maintain acceptable performance levels.

## **2.5. RLCS Constraints Overview**

The following constraints were factors in the development of the detailed requirements for the RLCS:

- a) Regulatory policies – There were no technical regulatory policies specifically covering this project. The Department of Information technology and the Department of Finance, Technology Investment Review Unit required the submission of a Feasibility Study Report (FSR), justifying the expenditure of State of California funds for the RLCS upgrade. These requirements were created to address each of the business problems and satisfy each of the objectives to be achieved by the RLCS upgrade, as stated within the FSR.
- b) Hardware limitations – The field devices currently installed (e.g. gates, pop-ups, CMS, etc) will not be changed to accommodate new software. The software and new computer hardware, including new I/O cards, must accommodate the existing field device hardware.
- c) Interfaces to other applications – Other than the RLCS status data to be made available on an external server data store, there shall be no interfaces to other applications.
- d) Parallel operation – For a short time, while the proposed RLCS is being rolled out into the field, the existing RLCS will be left in place and will only be disconnected after a successful, complete system test in the field during hours when the facility is closed to traffic.
- e) Audit functions – The RLCS will collect and store log files which will track all system operations.
- f) Higher-order language requirements – There are no specific high level language requirements, other than that a high level language be used to develop and maintain the system for more cost-effective maintenance efforts.
- g) Communications protocols– Each of the various field device sensors, as well as the intelligent controllers and network components will operate on open standards protocols.
- h) Reliability requirements – The system must be available 24 hours per day, 7 days per week, 365 days per year. In the event of a computer system failure (either a workstation or an intelligent controller), redundancy must be built into the RLCS system to reroute system data and control commands around the affected unit. See Section 3.6.1 *Reliability* for more details.
- i) Criticality of the application – The application is important to the traffic management goals of the Southern California region. Opening the lanes in the direction of the peak traffic flow to route traffic onto the I-15 Reversible Lane facility is a critical operation in meeting these goals.



j) Safety and security considerations – The safety of field maintenance staff and the traveling public is dependent on the correct functioning of the application to open and close the facility.

## **2.6. User Characteristics**

Several classes of users will access the RLCS. A user is defined as anyone authorized to 'log on' to the RLCS. External entities such as ATMS and ValuePricing, which will retrieve data from an external server data store are not considered users. Also, the motoring public will have access to system status via the changeable message signs, and eventually the Traveler Information Network, but are also not considered users of the system.

<b>User Class</b>	<b>Functions</b>
Operator	Issues commands to control the RLCS during normal, maintenance, and emergency modes. Only one 'operator' may be logged onto the system at any given time. Authorized to change system mode.
Management	Reporting and status checking capabilities only
Field Maintenance Staff	Issues commands to control the system only during maintenance mode. Ability to execute maintenance mode control sequences from FCU workstations or remote dial-in terminals, as well as from the maintenance building workstation, but not from the TMC workstation. Not able to change system mode.
Electrical Systems (Hardware)	In addition to reporting and status checking, also have the ability to run diagnostic, real-time queries of system devices.
Software Systems (Software)	In addition to reporting and status checking, also have the ability to access the system at lower levels (database, network, and client/server operating system).
System Administrator	A member of the District 11 technical staff (usually a Software Systems staff member) authorized to create and modify system configuration data, including staff, devices, and scheduled operations. Authorized to changed system mode.

## **2.7. Assumptions and Dependencies**

The RLCS will benefit from the deployment of the Fiber Optic Network along I-15 Reversible Lane corridor to include the RLCS lanes. The deployment is scheduled for completion by the Spring of 2003. The communications between the FCU and DCU locations will continue to be copper.

The existing leased lines provide a backup if the fiber is not available.

## **2.8. Operational Scenarios**

This section describes the RLCS operational requirements which are critical to designing a safe control system. This section also lays down operational rules, which the software must implement and adhere to.

### **2.8.1. Open Entrances**

RLCS facility entrances allow vehicles to enter from the adjacent main lanes of I-15 or SR-163. Each entrance serves only one direction of travel (either Northbound, or Southbound). Each entrance is, as necessary, opened in order to allow access to the facility, or closed in order to either close the facility, or open it in the opposing direction.

RLCS facility exits, used by vehicles to exit the facility, are always open and have no control devices associated with them.

In the direction of travel on the freeway, RLCS facility entrance closure devices consist of:

1. Changeable Message Signs (CMS)
2. Entrance Longitudinal Pop-ups
3. Entrance Transverse Pop-ups
4. Barrier Gates
5. Wrong Way Transverse Pop-ups
6. Wrong Way Longitudinal Pop-ups

Operation of each closure device will entail one or more commands from its associated control unit. Each command, which operates a single closure device, shall have a specific 'response time window' defined for successful command completion. In addition, each compound command, which includes more than one 'single device' command, shall have a specific 'response time window' defined for successful command completion of the compound command.

The control system must not attempt to open any entrance closure device, if the status of any opposite direction entrance closure device is 'unknown' or open'.

Steps within a command, or command group, shall be executed sequentially, whether the individual commands in a group, will be executed by one (1) control unit, or by more than one control unit.

### **2.8.2. Roadway Closure Device Status**

The current status of all entrance closure devices in the system must be maintained at each control unit. The state of the closure devices shall be updated in all control units. The update frequency shall be higher during the opening and closing periods. Closure device sensors shall be monitored continuously by their local control unit. The status should be forwarded immediately to all other control units in the system.

### **2.8.3. Opening Sequences**

Opening sequences must open Entrance devices in the following order:

1. Barrier Gate
2. Wrong Way Transverse Pop-ups

If more than one bank, banks are opened in the direction from the freeway toward the reversible lanes.

3. Wrong Way Longitudinal Pop-ups  
Pop-up banks are opened beginning at the entrance ramp nose at the reversible lanes, and proceeding toward the edge of shoulder.
4. Entrance Transverse Pop-ups  
If more than one bank, the banks are opened in the direction from the reversible lanes toward the freeway.
5. Entrance Longitudinal Pop-ups  
Pop-up banks are opened downstream (entrance ramp nose at the freeway) to upstream (edge of shoulder).
6. CMS  
CMS messages will be changed from a 'Closed' message, to an 'Open' message beginning with the furthest downstream sign (sign closest to the reversible lane), and proceeding upstream (away from the reversible lanes) as message change confirmations are received from each sign.

At any point in an opening sequence, the sequence shall be halted if:

- A device fails to report completion of the current sequence step within the response time window allotted for the step, or
- The status of a closure device for the opposite direction of travel changes to 'unknown' or 'open', or
- The status of a closure device, which was previously opened at the current entrance, changes to 'unknown' or 'closed'.

#### 2.8.4. Closing Sequences

Closing sequences must close Entrance devices in the following order:

1. CMS  
CMS messages will be changed from "Open" to "Closed" beginning with the farthest upstream sign (furthest away from the entrance) and proceeding, in order, downstream (towards the entrance). The system shall provide for a specific delay between the message change on each sign and the message change on the next downstream sign. The delay for each sign pair shall equal the time to travel between the two signs at a system specified speed.
2. Entrance Longitudinal Pop-ups  
Entrance Longitudinal Pop-ups must be closed in the direction of adjacent freeway traffic (beginning at the shoulder edge and proceeding toward the entrance ramp nose).
3. Entrance Transverse Pop-ups  
If more than one bank, Entrance Transverse Pop-ups will be closed in the direction from the freeway toward the reversible lanes.
4. Wrong Way Longitudinal Pop-ups  
Wrong Way Longitudinal Pop-ups will be closed beginning at the shoulder edge, and progressing toward the ramp nose, next to the reversible lanes.
5. Wrong Way Transverse Pop-ups  
If more than one bank, Wrong Way Transverse Pop-ups will be closed in the direction from the reversible lanes toward the freeway.
6. Barrier Gate

At any point in a closing sequence, the sequence shall be halted if either:

1. A device fails to report completion of the current sequence step within the response time window allotted for the step, or
2. The status for a closure device, which was previously closed at the current entrance, changes to 'unknown' or 'open'.

### 2.8.5. 'Halted' Opening and Closing Sequences

A 'halted' opening or closing sequence shall cause the system to enter a 'hold' state for a system specified time. If the offending device status can be corrected within the specified time period, the operator shall be able to enter a 'resume' command in order for the system to attempt to complete the original opening/closing sequence.

### 2.8.6. Multiple Entrances

If multiple entrances exist on the reversible lanes in the direction of travel being opened, the specific order in which those entrances are opened presents no 'wrong way' safety issues. Likewise, if multiple entrances exist on the reversible lanes in the direction of travel being closed, the specific order in which those entrances are closed presents no 'wrong way' safety issues.

### 2.8.7. Safety Screening of Commands

Safety screening shall be done to determine if execution of a proposed command, if successful, would produce a valid reversible lanes configuration. If the screened command, including any subordinate commands would result in an unacceptable reversible lanes configuration, the screening check is considered to have failed.

In the following section, the term 'device command' shall be understood to include any simple command, command group, or macro, which may, if executed, change the state of one or more entrance devices.

In the case of device command groups (macros, compound commands, etc.) any screening requirement shall be applied to the command group, and to each device command within the group, prior to execution.

Each instance of safety screening shall utilize system configuration data that is no more than 3 seconds old.

Safety screening of device commands shall be multi-layered.

1. Safety screening shall be applied to all device commands at the originating control unit, and at all subordinate control units to which the device command or any of its subordinate device commands may be forwarded.
2. Safety screening shall always be applied to any device command, or command step, by any control unit which directly operates the target entrance closure device(s), just prior to actual command execution.

An opening or closing sequence shall be halted, with an appropriate error response to the system operator, if, at any sequence step, command safety screening fails.

### 2.8.8. Control System Integrity

#### Control Unit Non-Volatile Memory

In each FCU and DCU in the system, the following items shall be replicated from the central database server and maintained in non-volatile, non-removable memory:

- Login Tables
- Closure Device Timing Parameters
- Air Calibration Factors
- Reversible Lanes Configuration Table(s)



### 2.8.9. Control System Integrity Verification

The system will employ a one-way hash function as an aid to encrypting and maintaining the integrity of the data and software in the field. The hash value returned by the function will be at least 128 bits in length. The MD5 algorithm, or future versions of MD5, is required for this purpose. This algorithm will reside in all the controllers and the application server.

At each time, one or more of the above item types, listed under 'Control Unit Non-Volatile Memory', is created or modified, a UTC date/time stamp will be appended to the code (or table). The appending of the time stamp will be the last step in the process which builds the time stamped code/data section.

The system will also, for each control unit in the system, produce a table of the returned 'one-way hash function' (Message Digest) values, of each of the 'Control Unit Non-Volatile Memory' items. The returned 'Message Digest' values will be stored as hexadecimal characters. The appropriate 'Message Digest' table will be maintained in non-volatile memory in each system control unit.

The system will provide for periodic verification that current, recomputed 'Message Digest' values, for each unit in the system, correspond with 'record' values computed by the MD5 algorithm. The periodic evaluation will occur at least once a day. The 'Message Digest' value verification results will be recorded in the system log. A verification failure will cause an alarm condition for the affected control unit. If the failure occurs in checking the non-volatile memory items, the system will prevent the affected unit from being used in control sequences.

The system will provide for 'Message Digest' verification requests for a given unit by operator command.

For system login purposes, the hash function will also be used to encrypt user passwords.

The system will provide for password aging. Whether or not the system will require password aging will be controllable by the System Administrator.

The system will provide for minimum username and password lengths. The minimum length values will be controllable by the system administrator.

### 2.8.10. Access and Safety Characteristics of the I-15 Reversible Roadway

The software must implement.

#### Characteristics Bearing on Security

##### 1. Isolation –

System commands may be entered only at a control unit console following logon. Command pathways are hard-wired, and not shared with other devices or systems. The current state of the roadway may be transmitted from the upper control unit (TSU) to another system via a one-way serial link if the firewall and/or network connection is unavailable. The Reversible Lane Control System does not accept or process any inputs from other systems.

##### 2. Closure Device Status Circulation –

The current state of each roadway closure device and device status change is circulated to all control units in the system, every 2 seconds.



## 3. Command Forwarding –

Commands are only forwarded from superior units to inferior units. This prevents a lower level unit from changing the state of a device which is controlled by either a higher level unit, or by a peer unit.

## 4. Command Processing –

Device control units utilize device feedback, coupled with strict response time windows for device opening and closing commands.

## 5. Uncertain status –

Unknown, or improper closure device status anywhere in the system, will immediately terminate a 'device opening' command. Improper device status 'may' terminate a device closing command, or sequence.

**Physical Access/Control Table**

Access Point	Control Ability
TMC	All RLCS Closure Devices
FCU South	All RLCS Closure Devices
DCU 1	NB 15 Entrance Wrong Way Devices and Gate
DCU 2	NB 163 Entrance Devices and Gate
DCU 3	NB 163 Wrong Way Devices
FCU North	All RLCS Closure Devices
DCU 4	SB 15 Wrong Way Devices
DCU 5	SB 15 Entrance Devices and Gate
CMS 1-12	Individual CMS Control



### 2.8.11. Normal Operations (Operator is logged on)

The system must allow the following scheduled operations at a minimum during 'normal' operational mode:

Sequence #1: Goal State: Open South Bound (AM) / Initial State: Closed (PM)  
AM Opening South Bound at 5:20 AM. (Initially Gate 5 at Loc. 5 is OPEN)

Step #	Operation	Device	Location
	Status check by Operator	All	All
1	CLOSE	Gate 1	Loc. 1 South End 15
2	CLOSE	Gate 2	Loc. 2 South End 163
3	OPEN	WW-Pop-ups	Loc. 4
4	OPEN	Draw Light	North End 15
5	OPEN	EN-Pop-ups	Loc. 5
6	OPEN	CMS 9-12	North End 15

Sequence #2: Goal State: Closed (AM) / Initial State: Open South Bound (AM)  
AM Closing South Bound at 11:00 AM

Step #	Operation	Device	Location
	Status check by Operator	All	All
1	CLOSE	CMS 9-12	North End 15
2	CLOSE	EN-Pop-ups	North End 15
3	CLOSE	WW-Pop-ups	North End 15
4	OPEN	Gate 1	Loc. 1 South End 15
5	OPEN	Gate 2	Loc. 2 South End 163

Sequence #3: Goal State: Open North Bound (PM) / Initial State: Closed (AM)  
PM Opening North Bound at 11:15 AM

Step #	Status	Device	Location
	Status check by Operator	All	All
1	CLOSE	Gate 5	Loc. 5 North End 15
2	OPEN	WW Lights	Loc. 4 North End 15
3	OPEN	WW-Pop-ups	South End 163
4	OPEN	WW-Pop-ups	South End 15
5	OPEN	EN-Pop-ups	South End 15
6	OPEN	CMS 1-4	South End 15
7	OPEN	EN-Pop-ups	South End 163
8	OPEN	CMS 5-8	South End 163

Sequence #4: Goal State: Closed (PM) / Initial State: Open North Bound (PM)  
PM Closing of RLCS at 7:00 PM.

Step #	Status	Device	Location
	Status check by Operator	All	All
1	CLOSE	CMS 1-4	South End 15
2	CLOSE	EN-Pop-ups	South End 15
3	CLOSE	WW-Pop-ups	South End 15
4	CLOSE	CMS 5-8	South End 163
5	CLOSE	EN-Pop-ups	South End 163
6	CLOSE	WW-Pop-ups	South End 163
7	CLOSE	WW-Lights	North End 15
8	OPEN	Gate 5	North End 15



#### 2.8.12. Unattended Operations (No operator logged on)

When no operator is logged on to the system, the status of all devices will continue to be monitored and displayed. If a scheduled operational sequence requires an operator to be logged on to confirm each step of the operation, an audible alarm will sound to alert the operator to log on to the system.

#### 2.8.13. Simulator Environment

The RLCS shall operate in a simulated architecture just as in the field, with the same functionality as in the system. The simulation environment will be used for hardware and software testing and training, as well as demonstration purposes.

#### 2.8.14. Training Functions

The RLCS will not include specialized training functions. The simulator environment shall allow users to learn how to operate the system using the actual software.

#### 2.8.15. Database Administration Support Functions

The RLCS shall not include any specialized database administration functions. All such functions will be dependent on the commercial off-the-shelf (COTS) database management system selected for the system, as well as on Department of Transportation Information Technology (IT) standards.

#### 2.8.16. Backup and recovery operations

The Department Operational Recovery Plan (ORP) is currently in the process of being updated. The new RLCS will be built with redundant capabilities with automatic switchover in case of system failure. This project proposes to maintain the configuration database locally as part of the failover design. Due to its rather limited complexity, the archival elements of the database will also be maintained locally. Primary communications to the North and South control buildings will be a fiber network, secondary communication will be leased lines. Dial-up lines connected to the FCUs will be used in the event of communication loss with the TMC to open and close the lanes. The ultimate operational backup for the RLCS devices has been and will continue to be manual operation with controls in the cabinets near the field devices.

#### 2.8.17. Data archiving

RLCS data shall be archived after 13 months.



### 3. System Capabilities, Conditions, and Constraints

#### 3.1. External interface requirements

##### 3.1.1. Hardware Interfaces

**Priority: Must have**

The RLCS must interface with existing field device hardware shown in **Exhibit 3.1** and **Exhibit 3.2a**, and currently in use at the facility.

Field Device	Description	FCU-S*			FCU-N*		Comments
		DCU 1*	DCU 2*	DCU 3*	DCU 4*	DCU 5*	
MCU	Manual Control Unit	1	1	1	1	1	Type of devices Controlled by each FCU controller.
Gate	Barrier Gate	1	1	0	0	1	
Draw Lights	Entrance Street Lights	1	1	0	0	1	
Wrong Way Lights	Barrier Lights	1	0	1	1	0	
EL-1	Longitudinal Entrance Pop-Up	3	2			5	Number of pop-ups per bank.
EL-2	Longitudinal Entrance Pop-Up	5	5			6	
EL-3	Longitudinal Entrance Pop-Up	4	9			6	
EL-4	Longitudinal Entrance Pop-Up	5				6	
EL-5	Longitudinal Entrance Pop-Up	6				3	
ET-1	Transverse Entrance Pop-Up	7	9			8	
WL-1	Longitudinal Wrong Way Pop-Up	4		4	4		
WL-2	Longitudinal Wrong Way Pop-Up	5		5	7		
WL-3	Longitudinal Wrong Way Pop-Up	5		7			
WL-4	Longitudinal Wrong Way Pop-Up	4		7			
WL-5	Longitudinal Wrong Way Pop-Up			7			
WT-1	Transverse Wrong Way Pop-Up			5	10		
WT-2	Transverse Wrong Way Pop-Up	6			11		
CMS 1-4	I-15 northbound RLCS approach						Controlled from FCU South
CMS 5-8	SR 163 northbound RLCS approach						Controlled from FCU South
CMS 9-12	I-15 southbound RLCS approach						Controlled from FCU North

**Exhibit 3.1: I-15 RLCS Controllers and Field Devices**

\*The controllers at the FCU and DCU will be replaced with modern controllers such as the Department of Transportation 2070 Advanced Transportation Controller (ATC) or a controller with equal or better capabilities.



**RLCS Inputs to and outputs from the FCU and DCU Controllers**

Field Device	Device Sensors	Inputs Or Outputs	FCUS	FCU-N	DCU 1	M C U 1	DCU 2	M C U 2	DCU 3	M C U 3	DCU 4	M C U 4	DCU 5	M C U 5	Total # of Sensors
Barrier Lights	LHS and LHN Light	Output	4	4	1	0	1	0	1	0	1	0	1	0	13
FCUs and DCUs	Cabinet ID	Input	4	4	4	0	4	0	4	0	4	0	4	0	28
	Compressor Pressure	Input	1	1	0	0	0	0	0	0	0	0	0		2
MCU	Air Tank Press	Input	1	1	0	1	0	1	0	1	0	1	0	1	7
	Line Air Press	Input	0	0	0	1	0	1	0	1	0	1	0	1	5
	Auto/ Manual	Input	0	0	0	1	0	1	0	1	0	1	0	1	5
Pop-Ups	Pop-Up Power Enable	Output	0	0	1	0	1	0	1	0	1	0	1	0	5
	Pop-Up Entrance Up	Output	0	0	6	0	4	0	0	0	0	0	6	0	16
	Pop-Up Entrance Down	Output	0	0	6	0	4	0	0	0	0	0	6	0	16
	Pop-Up Wrong Way Up	Output	0	0	5	0	0	0	6	0	4	0	0	0	15
	Pop-Up Wrong Way Down	Output	0	0	5	0	0	0	6	0	4	0	0	0	15
CMS	CMS	Input/Output	8	4	0	0	0	0	0	0	0	0	0	0	12
Gate	Gate Power Enable	Output	0	0	1	0	1	0	1	0	0	0	1	0	4
	Gate Warning Lights	Output	0	0	1	0	1	0	1	0	0	0	1	0	4
	Gate Up	Input/Output	0	0	1	0	1	0	1	0	0	0	1	0	4
	Gate 15 Deg. Down	Input/Output	0	0	1	0	1	0	1	0	0	0	1	0	4
	Gate Down	Input/Output	0	0	1	0	1	0	1	0	0	0	1	0	4
	TOTAL # OF SENSORS:		18	14	33	3	19	3	23	3	14	3	23	3	159

**Exhibit 3.2a: Currently installed I-15 RLCS Field Sensors and Devices**

**Devices to be added to the RLCS are shown in Exhibit 3.2b.**



**RLCS Inputs to and outputs from the FCU and DCU Controllers**

Field Device	Device Sensors	Inputs Or Outputs	FCU-S	FCU-N	DCU 1		DCU 2		DCU 3		DCU 4		DCU 5		Total # of Sensors
FCUs	Watchdog Timer	Output	1	1	0		0		0		0		0		2
FCUs/DCUs	Watchdog Status	Output	1	1	1		1		1		1		1		7
	Temp	Input	1	1	1		1		1		1		1		7
	Voltage	Input	1	1	1		1		1		1		1		7
	Cabinet Door Sensor * MCU	Input	0	0	2	2*	2	2*	2	2*	2	2*	2	2*	20
* Also in MCU	TOTAL # OF SENSORS:		4	4	7		7		7		7		7		43

**Exhibit 3.2b: Future Installation I-15 RLCS Field Device and Sensors**

### 3.1.2. Software interfaces

**Priority: Must have**

The RLCS will interface with an external computer to update the external server data store with RLCS Lane Status data as described in External RLCS Interfaces

### 3.1.3. Communications interfaces

**Priority: Must have**

There are two external communications interfaces with the RLCS.

3.1.3.1 The first is a one-way connection to the external data store outside the RLCS via a firewall to enable update of RLCS lane status data. Alternatively, should the firewall not be in operation, a one-way serial link would be used to transfer system status.

3.1.3.2 The second consists of the remote dial-in interface through a firewall via a dial-up modem. This is a two-way interface that allows connection into the RLCS network via a remote computer equipped with the application software, and with a user logon authorized for remote access.

## 3.2. RLCS Functional Characteristics

This section describes the fundamental actions that must occur to accept RLCS inputs and produce RLCS outputs.

### 3.2.1. Application Software

**Priority: Must have**

The application software allows an operator to view system status and issue commands to change device status as well as configure the system, export log data, and generate reports. The five major functions of the RLCS application software are a Graphical User Interface (GUI), Process Control and Monitoring, Sequencing, Data Processing and Security, and Reporting.

#### 3.2.1.1 Graphical User Interface (GUI)

**Priority: Must have**

The system shall have a Graphical User Interface (GUI) that allows the operator to view system status, issue commands to change device status, configure the system, export log data, and generate reports via a COTS reporting system.

#### 3.2.1.2 Process Monitoring and Control

**Priority: Must have**

3.2.1.2.1 The RLCS shall monitor all field device sensors, and shall process operator requests for changing field device status.

3.2.1.2.2 Any operator or system command, which changes the state of field control devices, must be checked for integrity at multiple levels in the RLCS.

3.2.1.2.3 The RLCS software shall monitor, display, and update the database with the status of all system field elements. Any change in device state shall be reported on the screen not later than 2 seconds from the time it occurs. In addition to monitoring field devices the system shall also monitor field controllers and connected on the RLCS network for control system integrity. The system shall report any users logged on and all commands issued in the field units.

- 3.2.1.2.4 During 'degraded' mode, the system shall monitor device sensors at the frequency rate stored in the database to take effect only during 'degraded' mode. In general, the system shall monitor the status of all field devices at the frequency specified in the System Control Parameters for that mode.
- 3.2.1.2.5 The system shall control all system field elements to device sensor level for those device sensors that may be controlled. For example, the temperature sensor at the controller cabinet is not a controllable sensor, whereas the 'gate arm control lines' sensor may be controlled.
- 3.2.1.2.6 Each device control command shall check the current status of all closure devices in the system and shall abort if any closure control device status is unknown.
- 3.2.1.2.7 Each command (at the device sensor command, device command(macro), or system operational command (super macro) level) shall only be executed when a valid or good status exists for all device sensors. An authorized user shall be able to log in and issue device status requests and control commands from specified computers in the network. (This is determined based on the user's access level and authorized workstations.)
- 3.2.1.2.8 The current status for all devices shall be maintained at each controller unit.
- 3.2.1.2.9 Alarms  
Check Device Status for Alarm Condition  
Each status received from device sensors shall be checked against alarm conditions for that device sensor and the status will be updated to indicate an alarm.
- 3.2.1.2.10 Critical alarms shall be generated when one or more of these conditions are met.
- 1) A closure device changes from a known state to unknown state (status lost)
  - 2) A closure device changes from legal state to illegal state. E.g. pop-ups in the down position when they are supposed to be up.
  - 3) The control system Integrity verification indicates a verification failure.
  - 4) When a user logs in any of the field units.
  - 5) When a command to override a device has been issued anywhere in the system.
  - 6) When there is a communication failure within the RLCS network
  - 7) When a computer in the RLCS network goes down
  - 8) Power failure at any controller or workstation
  - 9) When a cabinet ID is changed.
  - 10) When the DCUs are in manual mode.
  - 11) Watch Dog timer failure
- 3.2.1.2.11 Warning alarms shall be generated when one or more of these conditions are met.
- 1) security sensor activation at either the FCU or DCU.

- 2) When Air pressure, Temperature in cabinets, and Voltages are outside the limits of established thresholds as stored in the database.

3.2.1.2.12 If a critical alarm occurs during opening or closing operation, the system shall present the operator with possible actions that can be taken in order to complete the operation. If overriding a device status is needed in order to proceed, the system shall determine if the operator has high enough security and provide advise on how to proceed.

#### 3.2.1.2.13 Process GUI Commands

3.2.1.2.13.1 In order for a command to be processed from any workstation or controller, the MCU field device shall be in the "Auto" mode.

3.2.1.2.13.2 The system operator shall be able to override any device and continue with a system operational command sequence. To 'override' a device means to set the status to a normal value even if the device is not functioning in order to continue with a sequence. Field staff would manually operate any device that is not responding to a controller command prior to the operator 'overriding' the device status.

3.2.1.2.13.3 The process of overriding a device status shall not affect the status of any other device.

#### 3.2.1.2.13.4 Business Rules / Interlocks / Safety Screening

Each control command that is processed must be validated against the secured safety rules (stored in non-volatile memory) for the command. For example, if the operator issues a command to open the south gate while the north gate is open, the RLCS software will determine that opening the south gate cannot occur when the north gate is open, and will give an indication that the operation cannot be completed. The validation will occur at each control unit in the system that receives the command.

3.2.1.2.13.5 Commands are only forwarded from superior units to inferior ones. This prevents a lower level unit from changing the state of a device which is controlled by either a higher level unit, or by a peer unit. The TSU is superior to the FCUs which are superior to the DCUs.

#### 3.2.1.2.14 Track Failed Requests for Device Status and Control

3.2.1.2.14.1 If a status from any device is not received upon request, the system shall automatically request the status again.

3.2.1.2.14.2 Failure to receive a valid status after a configurable number of retries shall be considered a device failure.

#### 3.2.1.2.15 Identify and Initialize all Devices

3.2.1.2.15.1 When each control unit (workstation or intelligent controller at the FCU or DCU) comes online, the system shall identify it and all its associated device sensors.

- 3.2.1.2.15.2 The RLCS software shall initialize each control unit and device sensor as it is identified.
- 3.2.1.2.15.3 RLCS Software Startup PROCESS: The RLCS software in the field shall first identify its unit when it starts, by reading the cabinet id. The RLCS software will then proceed to make sure that all the cards required in that unit are present and working properly. The RLCS software will do a control system integrity check ( see requirement 3.0.9) and initialize all the specified tables. If everything is OK the start up process shall not exceed 30 seconds. The RLCS software shall then monitor all the devices and send the current status to the FCU or TSU every 2 seconds (or at the rate specified in the System Control Parameters for the current mode).
- 3.2.1.2.16 The RLCS software shall be designed to allow for future changes to the roadway without requiring programming effort. Updating non-volatile memory-based tables shall be sufficient to accommodate future changes to the roadway. Some examples of future changes to the facility include, change in the number of closure devices, change in the number of entrances to lanes, change in the number of changeable message signs, Different closure devices, different operational procedures.
- 3.2.1.1.17 Collect Log Data  
The system shall generate log files as follows for reports:
- 3.2.1.1.17.1 Device Command Log: Contains device commands issued with time stamp, operator ID, unit where the command was issued at and shall include failed or aborted commands. Device command log shall not be editable by users.
- 3.2.1.1.17.2 System Operation Command Log: Contains system operational commands issued with time stamp, operator ID, unit where the command was issued at and shall include failed or aborted commands. System Operation command shall not be editable by users
- 3.2.1.1.17.3 The Problem Work Order Log will be generated automatically with failure information at the time of failure. Some input fields in this log will allow the operator to input status and emergency notification information.
- 3.2.1.1.17.4 Alarm Log will contain information about warning and critical alarm events.
- 3.2.1.1.17.5 The Daily Diary Log will be generated automatically when a user with Operator authority logs on to the system. Some input fields in this log will allow the operator to input free form text information.
- 3.2.1.1.17.6 Special Event Log: This log will contain information about scheduled special events.
- 3.2.1.1.17.7 System Operation Schedule Log: This log contains information about scheduled operations.

### 3.2.1.3 Sequencing

**Priority: Must have**

3.2.1.3.1 The RLCS shall execute stored operational control command sequences based on the current system mode of operation and the schedule for each sequence. The operational control command sequences to be stored and executed with the initial configuration of the system are listed in Appendix F.

3.2.1.3.2 The RLCS shall present scheduled command operations to the operator at the GUI for confirmation prior to executing the command.

3.2.1.3.3 At any point in an opening or closing sequence, the sequence shall be halted if:

3.2.1.3.3.1 A device fails to report completion of the current sequence step within the response time window allotted for the step, or

3.2.1.3.3.2 The status of a closure device, which was previously opened at the current entrance, changes to 'unknown' or 'closed', without an operator-initiated command.

3.2.1.3.3.3 The status of a closure device, which was previously closed at the current entrance, changes to 'unknown' or 'open', without an operator-initiated command.

3.2.1.3.4 At any point in an opening sequence, the sequence shall be halted if the status of a closure device for the opposite direction of travel changes to 'unknown' or 'open'.

3.2.1.3.5 To resume an opening or closing sequence after a halt has occurred, the operator shall be able to issue a command to resume if the offending device status can be corrected within a configurable time period as defined in the database and in non-volatile memory.

### 3.2.1.4 Data Processing and Security

**Priority: Must have**

The RLCS shall store, process, and retrieve all data necessary to operate the application software as well as generate current and historical reports of system operations, and export system status data to an external server data store. The RLCS shall also store, process, and retrieve all data necessary to secure the system from unauthorized use. A commercial off-the-shelf database management system shall be used for this function.

The RLCS database stores information needed to operate the RLCS as well as historical transaction data to generate reports of system operations.

The entities in Exhibit 3.3 fulfill the functional requirements of the RLCS, but the list does not include any data that might be included with a vendor's pre-packaged COTS system or custom-designed solution. Additional data entities required for design or included with a COTS system are not disallowed by this specification.

An Entity Relationship Diagram and Relationship Descriptions are included in Appendix G.



## I-15 RLCS System Requirements Specification

#	Entity Name	Minimum Attributes
1	Agency	Agency ID, Agency Name, Contact, Address, Phone
2	Alarm Type	Alarm Type ID, Description (critical, warning)
3	Command Level	Command Level ID, Name (examples: status, control, override), type(status/control)
4	Customer Type	Customer Type ID, Name (examples: general public, FasTrak, HOV)
5	Device	Device ID, Name, Device Status ID, graphic image for display, location ID, direction, Device Category ID, Last Maintenance Date
6	Device Alarm Criteria	Device Alarm Criteria ID, Device ID, Alarm low range, Alarm high range, Alarm Description, Device Status ID
7	Device Category	Device Category ID, Name, Description of category
8	Device Command	Device Command ID, Device ID, Command String, Timeout, Command Level
9	Device Command Macro	Device Command ID, Device ID, Command Name, Command String, Timeout, Command Level
10	Device Command Log	Device Command Log ID, Device Command ID, Date, Time, Device Status ID, Operator ID
11	Device Command Steps	Device Command Steps ID, Device Command ID, Step #, Device Command
12	Device Rules	Device Rules ID, Mode, Device X desired status, Device Y prohibited status
13	Device Status	Device Status ID, Name, Description of status (e.g. ok, alarm)
14	Diagnostic Command	Diagnostic Command ID, Name, Diagnostic Program Path and Name, Command Level
15	Emergency Notification Profile	Emergency Notification Profile ID, Schedule Shift, Alarm Type ID, Personnel ID, Pager #, Telephone #
16	Location	Location ID, Highway #, Segment, Direction, Lane #, geo code, Name
17	Operator Daily Diary Log	Operator Daily Diary Log ID, Personnel ID, Date, Notes
18	Personnel	Personnel ID, Name, Initials for login, password, password date
19	Personnel Classification	Personnel Classification ID, Name, Description of classification
20	Personnel Security Level	Personnel Security Level ID, Mode, Functions, Command Level, Devices, Workstation
21	Personnel Security Level Device	Personnel Security Level ID, Device ID
22	Personnel Status	Personnel Status ID, Name, Description of status (active & logged on, active & logged off, inactive)
23	Personnel System Functions	Personnel ID, Function ID
24	Personnel System Modes	Personnel ID, System Mode ID
25	Personnel Workstations	Personnel ID, Workstation ID
26	Problem Work Order	Problem Work Order ID, Date, Time, Operator, Problem Work Order Status ID, Description
27	Problem Work Order Personnel	Problem Work Order ID, Personnel ID
28	Problem Work Order Status	Problem Work Order Status ID, Name, Description of status
29	Problem Work Order Type	Problem Work Order Type ID, Name, Description of type
30	Report Parameters	Report Parameters ID, Report name, Report number, Report begin date, Report end date
31	Sign Message	Sign Message ID, Name (e.g. "Express Lanes Open", "Express Lanes Closed")
32	System Control Parameters	System Control Parameters ID, System Mode ID, Login retry count, Polling rate, Override timeout, Max users, Display colors, Software version, Database version, Username length, Password length
33	System Functions	System Functions ID, Function Name
34	System Mode	System Mode ID, Name, (Normal, Degraded, Emergency, Maintenance, and others as defined)
35	System Operation Command Log	System Operation Command Log ID, Date, Time, System Operational Command ID, System Operation Status ID, Operator ID
36	System Operation Command Schedule	System Operation Schedule ID, Mode, Start day/time, End day/time, Frequency, System Operational Command ID or Device Command Macro ID, or Device Command ID. This entity can reflect items scheduled in advance that repeat at a set period, and can reflect items entered into the system for immediate execution.
37	System Operation Status	System Operation Status ID, Name (Open North, Open South, Closed), Customer Type ID
38	System Operational Command Steps	System Operational Command Steps ID, System Operational Command ID, Step #, Device Command
39	System Operational Command (super macro)	System Operational Command ID, Name, Description, Timeout, Command Level
40	Workstations	Workstation ID, Name, Location, Make, Model

**Exhibit 3.3: I-15 RLCS Entities and Attributes**

- 3.2.1.4.1 The RLCS application software shall update and read database tables to support system operations.
- 3.2.1.4.2 The RLCS application software shall Update and read password and device rule data in encrypted format.
- 3.2.1.4.3 Update and read Security information  
The Personnel Security Level entity stores information about the five attributes used to restrict access to the RLCS: Command Level, Device, Mode, Workstation, and System Functions.
- 3.2.1.4.4 Command levels are of three types: 'Status Only', 'Control', and 'Override'. Users with 'Status Only' command level security may not issue any control commands at any level (device, macro, or super macro). 'Control' allows a user to issue control commands, and is a higher level of security. 'Override' allows a user to temporarily change the status of a device in the database for a configurable period of time in order to allow a command sequence to continue.
- 3.2.1.4.5 Commands shall be classified in these categories
  - (1) Device control commands. These are single commands that change the state of a device. Example: Raise gate at location 1
  - (2) Device Macro Commands. This is a group of two or more sequentially executed commands that change the states of two or more closure devices. Example Close CMS 1 through 4.
  - (3) Super Macro Commands. This is a group of two or more sequentially executed macros that change the states of an Entrance. Example Close South end Location 2.
  - (4) Override Commands. These are commands that force the status of a device to a temporary known state for the purpose of completing an operation which otherwise would not be completed if the device remained in an unknown state. This type of command changes the database value for the device only and does not send a device command to the field device.
  - (5) Device Status Commands. These are commands that request the status of a device. Example Get status of DCU1, or get the status of CMS12.
  - (6) Diagnostic Commands. These are commands that run diagnostic on devices or controllers. Example: Run diagnostics on the communication card in DCU1.
- 3.2.1.4.6 The system will employ a one-way hash function as an aid to maintaining the integrity of the data and software in the field. The hash value returned by the function will be at least 128 bits in length. The MD5 algorithm is acceptable for this purpose.

- 3.2.1.4.6.1 At each time, one or more of the above item types, listed under 'Control Unit Non-Volatile Memory', is created or modified, a UTC date/time stamp will be updated. The update of the time stamp will be the last step in the process which builds the time stamped code/data section.
- 3.2.1.4.6.2 The system will also, for each control unit in the system, produce a table of the returned 'one-way hash function' (Message Digest) values, of each of the 'Control Unit Non-Volatile Memory' items. The returned 'Message Digest' values will be stored as hexadecimal characters. The appropriate 'Message Digest' table will be maintained in non-volatile memory in each system control unit.
- 3.2.1.4.6.3 The system will provide for periodic verification that current, recomputed 'Message Digest' values, for each unit in the system, correspond with 'record' values computed by the MD5 algorithm. The periodic evaluation will occur at least once a day. The 'Message Digest' value verification results will be recorded in the system log. A verification failure will cause an alarm condition for the affected control unit. If the failure occurs in checking the non-volatile memory items, the system will prevent the affected unit from being used in control sequences.
- 3.2.1.4.6.4 The system will provide for 'Message Digest' verification requests for a given unit by operator command.
- 3.2.1.4.6.5 For system login purposes, the hash function will also be used to encrypt user passwords.
- 3.2.1.4.6.6 To change device command rules on the production system, the System Administrator must upload a new database version after testing the rule changes in the Simulator environment.

### 3.2.1.5 Reporting

#### **Priority: Must have**

The RLCS shall use the operational data exported from the database to create and format reports. A commercial off-the-shelf reporting tool shall be used for this function.

#### 3.2.1.5.1 Format Report for GUI Display

#### 3.2.1.5.2 Format Report for Print/Export Output

The following reports are representative of the reports to be produced by the system. Other reports could be produced from the data stored in the database.

- 3.2.1.5.3 Create "Current Command Summary Report" from System Command (Super Macro), Device Command (Macro), Device Command, Device Rules, System Operation Schedule, and System Operational Command Sequence Schedule entities.

- 3.2.1.5.4 Create "Event Log Report" from "Device Command Log", and "System Operation Command Log" entities.

- 3.2.1.5.5 Create “Current System Status Report” from System Operation Status Log entity for the current time.
- 3.2.1.5.6 Create “Schedule Report” from the “System Operational Schedule” entity.
- 3.2.1.5.7 Create “Failure Summary Report” from “Device Command Log”, and “System Operation Command Log” entities, for status value indicating a “failure”.
  - 3.2.1.5.7.1 The system shall generate problem reports based on alarms and system status reports
- 3.2.1.5.8 Create “Current User Report” from “Personnel Status” entity.
- 3.2.1.5.9 Create “Safety Report” from “Device Rules” entities.
- 3.2.1.5.10 Create “Operations and Maintenance Report” from “Device” entity using “Last Maintenance Date” attribute.
- 3.2.1.5.11 Create “System Status Report” from the ‘System Operation Status Log’ entity for a specified time period.
- 3.2.1.5.12 Create “Inventory Report” from “Device”, “Device Status”, “Device Category”, and “Location” entities.

### 3.2.2 Controller Hardware and System Software

#### **Priority: Must have**

3.2.2.1 Hardware: The current Transportation Electrical Equipment Specification (TEES) for the 2070 Advanced Transportation Controller (ATC) defines the minimum functionality required for the controller hardware component (FCUs and DCUs) of the RLCS. Other controllers having the same functional capabilities as the 2070 ATC are not excluded from consideration for use in this RLCS, but must be tested by Department of Transportation for compliance, at a minimum, with the 2070 standard.

3.2.2.2 Controller Operating System Software: The operating system software should include a user interface to enable the user to execute diagnostic programs to display the controller, I/O card, and field device statuses. The user interface, at minimum, should be a text-based command line interface.

3.2.2.3 Controller hardware and system software in the different FCU locations must work interchangeably. The hardware in one FCU must be the same type as hardware in another FCU, or in the simulator. New hardware in the different DCU locations must also work interchangeably.

### 3.2.3 Non-Controller Hardware and System Software

3.2.3.1 All non-controller hardware and system software such as application server, database server, and network servers, as well as printers, interface cards, and other peripheral devices will not have any specialized functionality beyond the functionality available in general purpose, commercially available devices.

3.2.3.2 Non-controller hardware and system software in the different FCU locations must work interchangeably. The hardware in one FCU must be the same type as hardware in another FCU, or in the simulator. New hardware in the different DCU locations must also work interchangeably.

#### 3.2.4 Communications

**Priority: Must have**

- 3.2.4.1 The RLCS will incorporate the State-furnished telecommunications network connections to accomplish communications between hardware and software components of the RLCS. The Department of Transportation will maintain the communication lines to adequately support the RLCS system requirements.
- 3.2.4.2 A user shall be able to access each unit of the control system (servers and field controllers) from anywhere on the network.

#### 3.2.5 Device Emulator Hardware and/or Software

**Priority: Must have**

- 3.2.5.1 The device emulator shall emulate each type of field device input and output and will be used in the simulator. In order to simulate field conditions, a field device emulator shall produce electrical signals for input to I/O cards residing in device controller hardware, and shall accept electrical signals from I/O cards residing in device controller hardware. Each type of field device defined in the system shall be emulated.
- 3.2.5.1 If the device emulation is implemented using software, a user interface shall be provided to control the devices (e.g. a button to raise , lower or disable a gate)
- 3.2.5.2 If the device emulation is implemented using hardware, mechanical switches shall be provided to control the devices (e.g. a switch to raise and lower pop-ups)
- 3.2.5.3 Each device shall be independently controlled
- 3.2.5.4 All the input and output signals from the device emulator shall be connected to the simulator DCUs and FCUs the same way as in the filed.

### 3.3. System Performance Characteristics

#### 3.3.1 External Interfaces

**Priority: Must have**

- 3.3.1.1. The external server data store containing RLCS status for use by external systems shall be updated once per minute.
- 3.3.1.2. The field device status information logging to the database shall be 2 seconds, but can be configurable within the database to more than 2 seconds by the user.
- 3.3.1.3. The field device status information display update frequency shall be 2 seconds, but can be configurable within the database to more than 2 seconds by the user.

3.3.1.4. The RLCS shall receive device status information from devices within 2 seconds of the status information being issued by the device.

3.3.1.5. Field devices shall respond to commands from the RLCS within 2 seconds of the command confirmation being issued by the operator using a keyboard (or other input device).

### 3.3.2 User Interface (GUI)

#### **Priority: Must have**

3.3.2.1 The RLCS shall support multiple users logged on, up to the limit of the number of users defined in the database.

3.3.2.2 Not including device and network response times, requests from the GUI for status updates shall not exceed 2 seconds to update the GUI display.

3.3.2.3 The facility map on the screen shall refresh every 2 seconds but can be configurable within the database to more than 2 seconds by the user.

3.3.2.4 The RLCS notification to the operator workstation of any critical alarms shall occur within 2 seconds of alarm detection, and shall occur whether or not an operator is logged on to the system.

### 3.3.3 Process Monitoring and Control

#### **Priority: Must have**

3.3.3.1 The field units (controllers) shall continually monitor device status, controller status and the control system integrity and send the status to the central computer in the TMC every 2 seconds or less.

3.3.3.2 The RLCS shall detect alarm conditions within 2 seconds of occurrence.

### 3.3.4 Sequencing

#### **Priority: Must have**

3.3.4.1 At a minimum of every 60 seconds, the system shall check the current date and time against a list of scheduled events for the current mode to determine if any event should be executed.

3.3.4.2 The RLCS shall support at a minimum the 4 daily 'normal' mode open and close scheduled operations plus at least the same number of 'emergency' and 'maintenance' mode scheduled events.

### 3.3.5 Data Processing and Security

#### **Priority: Must have**

The database retrieval and update response time shall not impact any other performance requirements such as the GUI response time or monitoring and control responses. In other words, the database performance is a component of the total response time for any other performance requirement. If the GUI is required to reflect change in status within 2 seconds, then the database update time must be less than 2 seconds.



### 3.3.6 Reporting

**Priority: Must have**

3.3.6.1 The operator shall be able to store and retrieve previously created report results from the RLCS for a minimum period of 60 days, but configurable for up to one year.

3.3.6.2 The raw data used to create reports shall be kept in the RLCS for a minimum period of 13 months prior to backing up to tapes or other secondary storage media.

3.3.6.3 Report processing shall not impact any other performance requirements such as the GUI response time or monitoring and control responses

3.3.6.4 Report response time shall be determined by the database resources allocated to the reporting function. Depending on user needs for fast report response times (such as for ad hoc reporting), database extracts may be created for reporting purposes only.

### 3.3.7 Controller Hardware and System Software

**Priority: Must have**

The Department of Transportation specification for the 2070 controller contains the minimum requirements for the performance of the controller hardware and system software for the RLCS.

### 3.3.8 Non-controller Hardware and System Software

**Priority: Must have**

The RLCS performance requirements for non-controller hardware and system software are based on the external and internal performance requirements of the system. Therefore the components selected must be capable of meeting these requirements.

### 3.3.9 Communications

**Priority: Must have**

3.3.9.1 RLCS system components will communicate via the private communications networks established by Department of Transportation District 11 prior to the development of the RLCS. Any operator or system command, which changes the state of field control devices, must be checked for integrity at multiple levels in the system. Valid checksum algorithms must be employed to check the integrity of messages between units.

3.3.9.2 The RLCS must support the following data transfer performance goals:

The number of kbits transmitted for a single polling event of all device sensors is estimated to be:

$$\begin{aligned} \text{\# of sensors} \times \text{bytes/status command} \times 8\text{bits/byte} \times 1\text{k}/1000 &= \\ 202 \times 200 \times 8 \times 1/1000 &= 323 \text{ kbits} \end{aligned}$$

The transmission rate required to transfer this data in 2 seconds is: 323 kbits/2 sec. = 162 kbits/s  
At a 30 second polling interval, the transmission rate drops to 10.9 kbits/s.

# of Sensors*	Bytes per status command	Polling Interval	Transmission Rate (kbits/second)
202	200	2	162
202	200	30	10.8

\*The # of sensors is the total # of sensors in **Exhibit 3.2a** and **Exhibit 3.2b** combined.



Polling all system devices constitutes the majority (over 99.99%) of transactions on the network. The opening and closing sequences that occur four times daily, add only a small fraction to the total system load.

At 162 kbits/s, in a 24-hour period, 13,996,800k bits will travel over the network:

$$(162 \text{ kbits/sec}) \times (60 \text{ sec/min}) \times (60 \text{ min/hr}) \times (24 \text{ hrs/day}) = 13,996,800 \text{ k bits/day}$$

The following chart shows the number of kbits added by the daily opening and closing operations, which represent only 0.009% of the daily system load:  $(1,293/13,996,800 = 0.00009)$

# of Sensors	Bytes per control command	# of control commands per day	Total k bits for control commands
<202	200	4	$(200 \times 202 \times 4 \times 8)/1000 = < 1,293 \text{ k bits}$

### 3.3.10 Device Emulator

#### **Priority: Must have**

The device emulator shall emulate the timing characteristics of each device.

## 3.4 System Operations and security

All data transmitted within the RLCS network and field units shall be encrypted using industry standard encryption methods.

### 3.4.1 System future expansion

The contractor shall be required to demonstrate the ability and the ease of adding future control devices to the system without the need of programming. Simulator is a separate and independent version of the RLCS, including an application server, and FCU and DCU controllers connected to a device emulator. DCUs 6 through 10 do not exist in the field, but are part of the simulator in order to test the system expandability. These DCUs contain the same device configuration as DCU number 1. CMSs 13 through 16 do not exist in the current system but will be part of the simulator in order to test future system expandability. These CMSs will be connected to FCU-N. We shall be testing the ability and the ease of adding future control devices to the system.

## 3.5 Design Constraints

### 3.5.1 Commercial Off-the-Shelf Software

#### **Priority: Must have**

3.5.1.1 The data processing and security, and reporting functions of the RLCS application software shall be implemented with commercial off-the-shelf software.

#### **Priority: Nice to have**

3.5.1.2 The data processing, security, and reporting functions as well as the server and client operating systems would preferably use the following:

- Oracle 9i for the database server and clients
- HP UX or Solaris server operating system (latest version)
- Windows NT or Linux for the client operating system (latest version)
- OS/9 or other real time operating system for the controller operating system
- Crystal Reports, Brio or comparable for reporting package

- AllFusion Change Manager or comparable for change and configuration management.

### 3.5.2 System Architecture

#### **Priority: Must have**

Although the system architecture has not been completely defined, the existing field device configuration will stay the same. The existing controllers will be upgraded.

3.5.2.1 The FCU and DCU controllers are currently set in a hierarchical configuration, which will not change.

3.5.2.2 The current TSU controller will be replaced by general purpose network, application, and database server hardware and software in the new architecture.

3.5.2.3 The communications capability between the FCU controllers and the DCU controllers is limited to serial communications, and will not be upgraded.

3.5.2.4 The CMS controllers are hard wired to the FCUs. Serial communication is used between the FCUs and the CMS controllers. This link will stay the same.

3.5.2.5 Cabinet wiring and cabling will be in accordance with TIA/EIA standards.

3.5.2.6 Hardware and system software components in the different FCU locations will work interchangeably. Hardware and system software in the different DCU locations will work interchangeably.

### 3.5.3 Client Workstations and Laptops

#### **Priority: Must have**

3.5.3.1 The production system will include the following 7 workstations:

- 2 workstations in the TMC for the operators.
- 2 workstation in the Field Control Unit sites (1 at each FCU, North and South).
- 1 workstation in the Maintenance Shop
- 1 workstation in the Department of Transportation electrical support room.
- 1 workstation in the computer systems room (for system administration purposes).

3.5.3.2 The production system will also include 4 laptops with the following functionality:

3.5.3.2.1 Must run the same application as the workstations when connected locally or dialed-in remotely to the network.

3.5.3.2.2 Must be able to perform controller diagnostics and control devices associated with a DCU when connected to a DCU.

3.5.3.3 The simulator system will include at least 2 separate workstations (or more if necessary, to simulate the production architecture) located in the computer systems room (to be shared by software, electrical, and training functions). One workstation will simulate the operations workstation, and one will be movable to test different workstation locations within the simulator.

3.5.3.4 The simulator system will include one laptop.

### 3.5.4 Controllers

**Priority: Must have**

In its current architecture, with the exception of replacing the TSU with network, application, and database servers, the system requires at least one controller at each of the two FCU buildings, plus at least one controller at each of the 5 DCU locations for a total of at least 7 controllers. The controllers at the DCU shall interface directly with the gate, pop-ups and draw light relay. It will also provide a mechanism to convert the voltage from the pressure transducers to the corresponding line and tank pressure. The controller shall also be capable of reporting the temperature and voltages, within the cabinet. The voltages would include the line voltage entering the controller/cabinet and any DC voltages, which may be used by the system (such as,  $\pm 5\text{v}$ ,  $\pm 12\text{ v}$ ,  $+24\text{ v}$ .)

The simulation/training system requires the same number of controllers as in the field.

### 3.5.5 Device Interface Cards

**Priority: Must have**

The production system requires device interface cards with optical isolation to handle all the sensors, one optical isolation for each sensor input and output. The simulator will have the same optical isolation as the field units.

### 3.5.6 Device Emulator

**Priority: Must have**

The simulator requires one or more field device emulator systems to simulate all the field device responses.

### 3.5.7 Security

**Priority: Must have**

3.5.7.1 The RLCS shall incorporate a database to store, process, and retrieve all data necessary to secure the system from unauthorized use.

3.5.7.2 The application software processing code and application software data such as login information at the FCU and DCU controllers shall be resident in non-volatile memory.

3.5.7.3 The MD5 algorithm shall be used to secure application data and software in the controllers and the application server.

### 3.5.8 Network

**Priority: Must have**

3.5.8.1 The RLCS shall operate within a private network to maintain security.

3.5.8.2 The primary communication media between the TSU (in the TMC) and the FCUs, as well as between FCU North and FCU South will be fiber.

3.5.8.3 Secondary communication media will be full duplex fractional T1 lines.

3.5.8.4 The primary communication method between the TSU and the two FCUs as well as between FCU North and FCU South shall be network based and shall be implemented using standard TCP/IP protocols.



3.5.8.5 Communication media between the FCUs and the DCUs is twisted pair (2 pair, each wire is AWG 18). The communication method is not restricted between the FCU and DCU (must be a standard serial or TCP/IP protocol).

3.5.8.6 The communication media between the FCUs and the CMS is twisted pair (2 pair, each wire is AWG 18). The communication method shall be serial and shall be implemented using standard RS232 protocol due to CMS interface limitations.

3.5.8.7 The RLCS software shall identify each unit (TSU, FCU, or DCU) and activate the proper primary communication methods.

(A) Between the TSU servers: 10/100 Mbit/s Ethernet

(B) Between The TSU and the FCUs: 10/100 Mbit/s Ethernet

(C) Between the FCU and the DCUs: full duplex 9600 b/s serial at a minimum, but a higher baud rate is preferred if achievable with the existing wiring.

(D) Between the FCU and the CMS controllers: full duplex 9600 b/s serial at a minimum, but a higher baud rate is preferred if achievable with the existing wiring.

### 3.5.9 Power

#### **Priority: Must have**

All RLCS cabinets and control facilities are powered by 120V AC and are backed-up by a stand by generator. An uninterrupted power supply with line conditioning shall be supplied to provide a minimum of 15 minutes of back-up power to each controller.

## 3.6 System Attributes

### 3.6.1 Reliability

#### **Priority: Must have**

3.6.1.1 To be accepted for use by the Department of Transportation, the RLCS must demonstrate the ability to function continuously without any down time, or without the need to be reset or rebooted due to an error in any part of the system for at least 30 consecutive days in both the simulator and field environments.

3.6.1.2 The mean time between failure (MTBF) value must not be less than 4,300 hours for electronic equipment and 26,000 hours for mechanical or electromechanical equipment installed within the RLCS. MTBF refers to the average time between the beginning of one failure to the beginning of the next failure for each machine.

The MTBF measurement (a) must encompass all instances where the hardware and system software has been previously installed in other systems, and (b) must be based on at least 1040 hours of use within a six-month period prior to installation in the RLCS.

#### **Calculation Method**

MTBF is calculated by dividing Up Time (UT) by the total number of failures. A "failure" is any system error or stoppage.

UT (Up Time) is defined as the time the system is available for productive work (i.e., the time the system is operating, but excluding Preventive Maintenance and Down Time); and



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DT (Down Time) is defined as the time the system could have been operating but is being repaired or is awaiting repairs, or is awaiting changes to or replacement of any system components (excluding any time when system repair is delayed by the Department of Transportation).

3.6.1.3 Valid checksum algorithms must be employed to check the integrity of messages between units.

3.6.1.4 The RLCS must be built with redundant capabilities to ensure uninterrupted operation. The RLCS will function in a degraded mode in the following manner:

3.6.1.4.1 If the TMC workstations or network server fails, resulting in loss of field status at the TMC, alternate control shall be at FCU South or FCU North. The operator shall be able to dial in from a back up computer to either FCU North or FCU south and open and close the reversible lanes.-

3.6.1.4.2 If FCU North or South fails: (FCU Controller failures or FCU-TSU communications failure) Loss of changeable messages signs and DCUs associated with the failed FCU. Alternate control at the non-failed FCU (North or South).

3.6.1.4.3 If FCUs North and South both fail: (FCU Controller failures or FCUs-TSU and FCU-FCU communications failure) Loss of changeable message signs 1-12 and DCUs 1-5. Alternate control units: Direct control at DCUs 1-5, and CMS 1-12 control from CMS cabinets. The operator shall be able to connect a lap top computer at the DCUs and operate the devices or perform manual operation from the MCU. The operator shall also be able to connect a lap top on the CMS cabinet and control the signs or perform manual operation of the signs from the cabinet.

3.6.1.4.4 If any DCU 1-5 fails: Field devices related to the failed DCU. Alternate control unit: MCU and manual control at the field devices.

3.6.1.4.5 If any MCU fails: Loss of field devices. Alternate control unit: Manual control at the field devices related to the failed MCU. The devices can be manually controlled/operated from their cabinets (e.g.: Gates)

3.6.1.5 The current configuration information for each processing unit in the field shall be duplicated in a database at the TMC level.

### 3.6.2 Availability

**Priority: Must have**

The RLCS must be available 24/7, 365 days per year. The normal operating mode is Monday through Friday, between 5:00am and 8:00pm, but the system must be functional in order to stay in its closed state after hours. If there is a failure, recovery time must be no greater than 10 minutes, and total yearly uptime must be at least 99.99% (.01% downtime, or approximately 50 minutes per year).

### Calculation Method

Equipment Availability is calculated by the formula:



$$\frac{UT \times 100\%}{UT + DT}$$

### 3.6.3 Maintainability

**Priority: Must have**

3.6.3.1 The RLCS shall support remote system administration and maintenance of the system.

3.6.3.2 The RLCS shall utilize an open architecture that is modular and scaleable.

3.6.3.3 Wherever possible open systems standards for hardware, software, software development tools, and communications shall be used.

### 3.6.4 Portability

There are no portability requirements.

## 3.7. Physical

### 3.7.1. Construction

**Priority: Must have**

3.7.1.1 The simulator facility will be constructed at the TMC in space provided by the Department of Transportation.

3.7.1.2 New controllers in the simulator environment will be mounted on racks at the TMC simulator facility.

3.7.1.3 The RLCS will be physically constructed to support the current field device configuration

3.7.1.4 New controllers in the production environment must be installed in parallel with the existing RLCS controllers. The new RLCS will be implemented without first disconnecting the existing/old RLCS. The deployment of this system shall not interfere with the operation of the existing RLCS. Parallel wiring and a switching mechanism will be provided by the Department of Transportation between old and new cabinets which will allow the new system to be switched on for testing purposes, and off for resumption of operating schedules with the old system until the new system is ready for production. Appendix H – System Cut-over Diagrams for Existing and New I-15 RLCS.

3.7.1.5 Cabinet wiring and cabling must be in accordance with the Telecommunications Industry Association (TIA) and Electronic Industries Alliance (EIA) standards.

3.7.1.6 New I/O cards must be installed in the new controller hardware.

3.7.1.7 New Controllers in the production environment will be installed in new cabinets furnished by The Department of Transportation.

3.7.1.8 None of the existing controller and I/O hardware will be used in the new RLCS.

### 3.7.2. Durability

**Priority: Must have**



The system hardware must be rated to perform within industry accepted normal ranges for each product, based on the environmental conditions.

### 3.7.3. Adaptability

**Priority: Must have**

The system software will minimize or eliminate programming needed to add or modify field devices characteristics using a high-level software environment for inclusion in all system data representations, including the graphical user interface, system log files and other data stores, field device lists, and reports.

### 3.7.4. Environmental Conditions

**Priority: Must have**

#### 3.7.4.1 Field Conditions

The device controllers and I/O cards in the field will need to withstand environmental extremes of heat, cold, and moisture. The current Transportation Electrical Equipment Specification (TEES) for the Advanced Transportation Controller (ATC) defines the environmental conditions tolerable by the 2070. Other controllers having the same durability as the 2070 ATC are not excluded from consideration for use in this system, but must be tested by Department of Transportation for compliance with the 2070 standard prior to contract award.

#### 3.7.4.2 Simulator Conditions

The simulator will reside indoors in the TMC and will consist of hardware and software representative of the entire RLCS, including simulated field devices.

The simulator will not have any differences in functionality. The simulation environment will be used for hardware and software testing and training, as well as demonstration.

The simulator will be used during initial RLCS development and afterward for

- Software module testing (unit testing)
- Integration testing
- Systems testing and modification
- Communication testing
- Training facility for operators and maintenance
- Future software and hardware upgrade and testing

Simulator hardware will consist of the same hardware components used in the field for the:

- Network server
- Database server
- Application server
- FCU controllers
- DCU controllers
- I/O cards

Communications protocols between all the units of the simulator will be the same protocol as in the field.

Signal processing and generating tools will be used to simulate the field device interfaces.

## 3.8 Policy and Regulation

There are no technical regulatory policies specifically covering this project. The Department of Information technology and the Department of Finance, Technology Investment Review Unit required



the submission of a Feasibility Study Report (FSR), justifying the expenditure of State of California funds for the system upgrade. The RLCS requirements are the basis for the RLCS application software requirements document created to address each of the business problems and satisfy each of the objectives to be achieved by the system upgrade, as stated within the FSR.

### **3.9 System Life Cycle Sustainment**

#### **Priority: Must have**

The system shall collect and present operational information (operational and error logs for the network and workstation operating systems, for example) to system managers and maintenance staff in such a way as to support ongoing lifecycle activities such as configuration management (version control, trouble reporting and tracking) and project management (planning, scheduling, and resource allocation).



## Appendix A – Requirements Working Group

<i>Position</i>	<i>Name</i>	<i>Company/Department</i>
Stakeholder	Ross Cather	Department of Transportation –Project Manager
Stakeholder	Fil Cunanan	Department of Transportation – Traffic Operations
Stakeholder	Don Day	Department of Transportation Software
Stakeholder	Dave Dutcher	Department of Transportation – Traffic Operations
Stakeholder	Lawrence Emerson	Department of Transportation – Traffic Operations
Stakeholder	Anupkumar Khant	Department of Transportation – Traffic Operations
Stakeholder	Harrison Makau	Department of Transportation – Software
Stakeholder	Brian Pecus	Department of Transportation – Traffic Operations
Stakeholder	David Pham	Department of Transportation – Software
Consultant	Larry Klein	VIP, Transportation Systems Specialist
Consultant	Lela Klein	VIP, Procurement Specialist
Consultant	Richard Robinson	VIP, FSR Specialist
Consultant	Karen Thurston	VIP, Requirements Specialist
Consultant	Fred Wood	VIP, Project Manager

Exhibit A.1: Requirements Working Group

**Appendix B – Terminology**

<b>Term</b>	<b>Definition</b>
ATIS	Advanced Traveler Information System
ATMS	Automated Transportation Management System
CMS	Changeable Message Sign or Signs
DCU	Device Control Unit
Device Override	The capability of the system to allow an operator with the proper security to continue an operating sequence through to the end even though any intermediate step resulted in a device control failure, by allowing the operator to input a device status thereby overriding the status coming from the field.
Facility	The I-15 Reversible Lane Facility. The physical roadway, field devices, and the RLCS.
FCU	Field Control Unit (Full description in Section 2.0.2 Architectural Description)
Field Devices	Gates, pop-ups, changeable message signs (CMS), lights, loop detectors, power, pressure transducers, and any other controlled device.
MCU	Manual Control Unit
MD5 Algorithm	An encryption algorithm that uses a private key
One-way Hash Algorithm	An algorithm used for encryption
Operational Override	The capability of the system to allow an operator with proper security to issue device commands outside of a predetermined operational event, on demand.
PIER	Post Implementation Evaluation Review
Real-time system	A real-time system responds in a timely, predictable way to external stimuli. A real-time system may have to operate under extreme load conditions. Other attributes of a real-time system: <b>Timeliness</b> : meet deadlines, it is required that the application has to finish certain tasks within defined time constraints. <b>Simultaneity or simultaneous processing</b> more than one event may happen simultaneously, and all deadlines should still be met. <b><u>Dependability or reliability</u></b> is required.
RLCS	The I-15 Reversible Lane Control System. The hardware, other electronic components and software used to monitor and control the field devices within the I-15 Reversible Lane Facility. Can refer to the existing or proposed RLCS.
RLCS Facility	The I-15 reversible lane physical roadway, field devices, and electronic components and software used to monitor and control the field devices.
RMIS	Ramp Metering Information System
TEES	Transportation Electrical Equipment Specification
TMC	Transportation Management Center
TSU	Traffic Systems Unit
UTC	Universal Time Coordinator



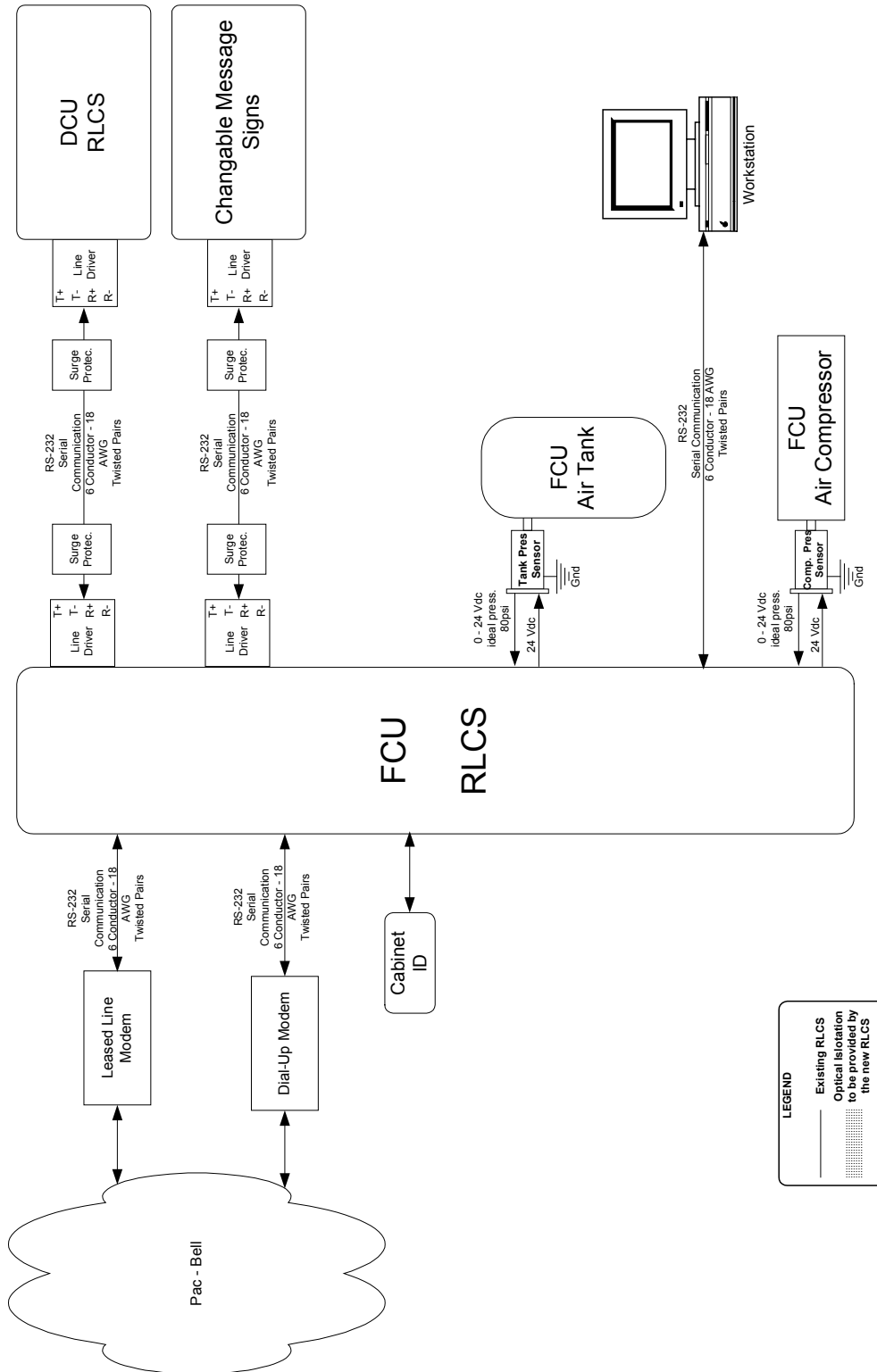
## Appendix C – Traceability Matrix from Version D to Version E

All requirements from Version D were retained. New requirements introduced in Version E are as follows:

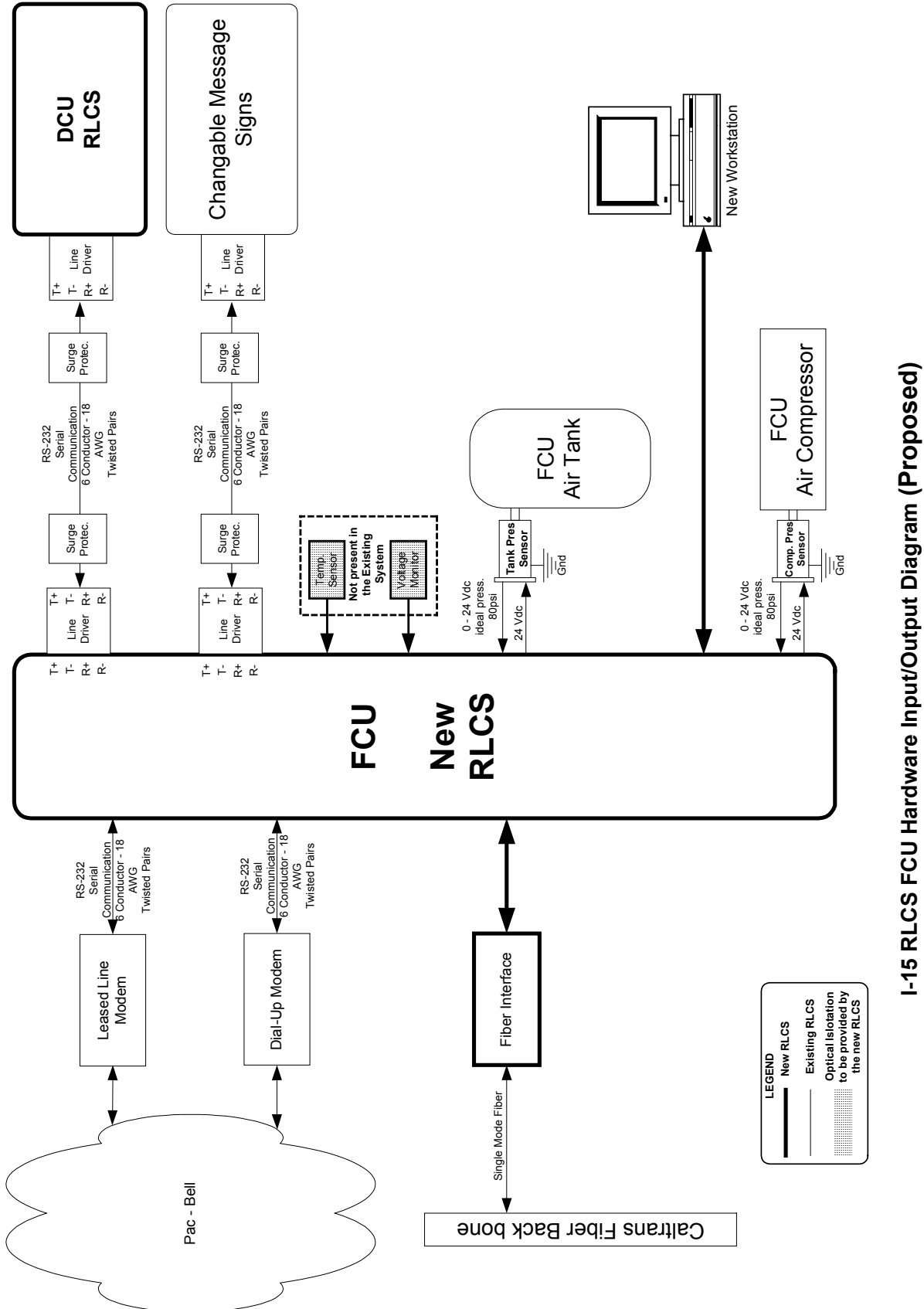
The following changes were made to version D of this specification to create Version E:

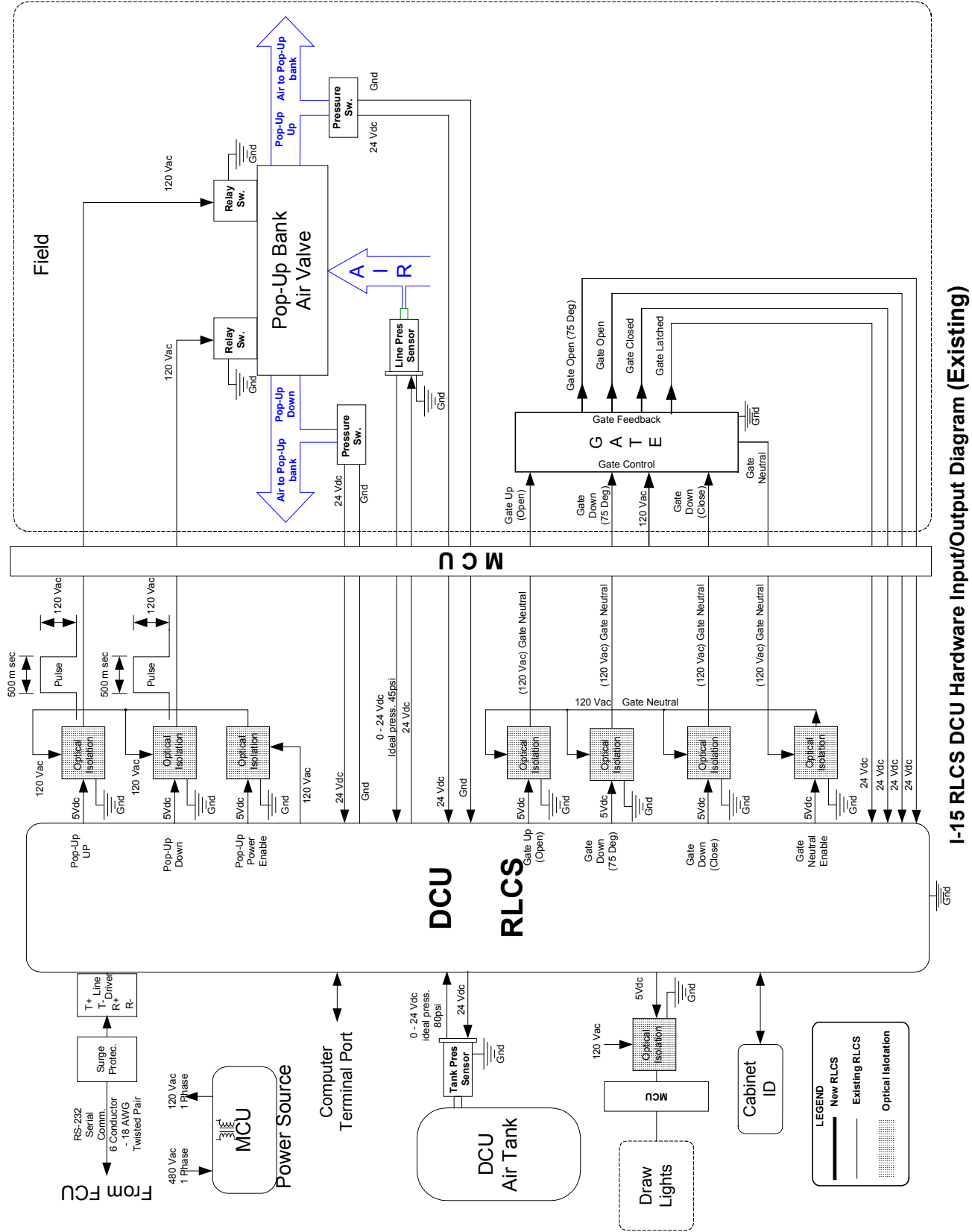
Section Number	Description of Change
1.4	Corrected the title of a reference document and added a link to the web URL.
2.0.3	Exhibit 2.4 diagram modified to show additional DCUs in the simulator for testing the expandability of the system. Also removed the LAN connection from the development server.
2.0.3	Added description of the DCUs 6 and 7, and modified text describing the device simulator
2.1.5	Reduced the number of pairs of twisted pair copper wire from 3 to 2.
2.3.2.2	Modified the description of the controller operating system software to include detail about diagnostic software.
2.3.5	Added new system capability: "Device Emulator Capabilities"
3.2.5	Added new system capability: "Device Emulator Hardware and/or Software"
3.3.10	Added new performance requirement for the device emulator capability
3.4.1	Future System Expansion (Also, referenced in 2.0.3)
3.5.8.5	Reduced the number of pairs of twisted pair copper wire from 3 to 2, and removed the restriction of a serial interface between the DCU and FCU.
3.6.1.1	Clarified the reliability requirement for 30 days continuous operation as being applicable to both the simulator and field environments.
F.9	Removed comment
F.10.1	Removed comment and clarified text

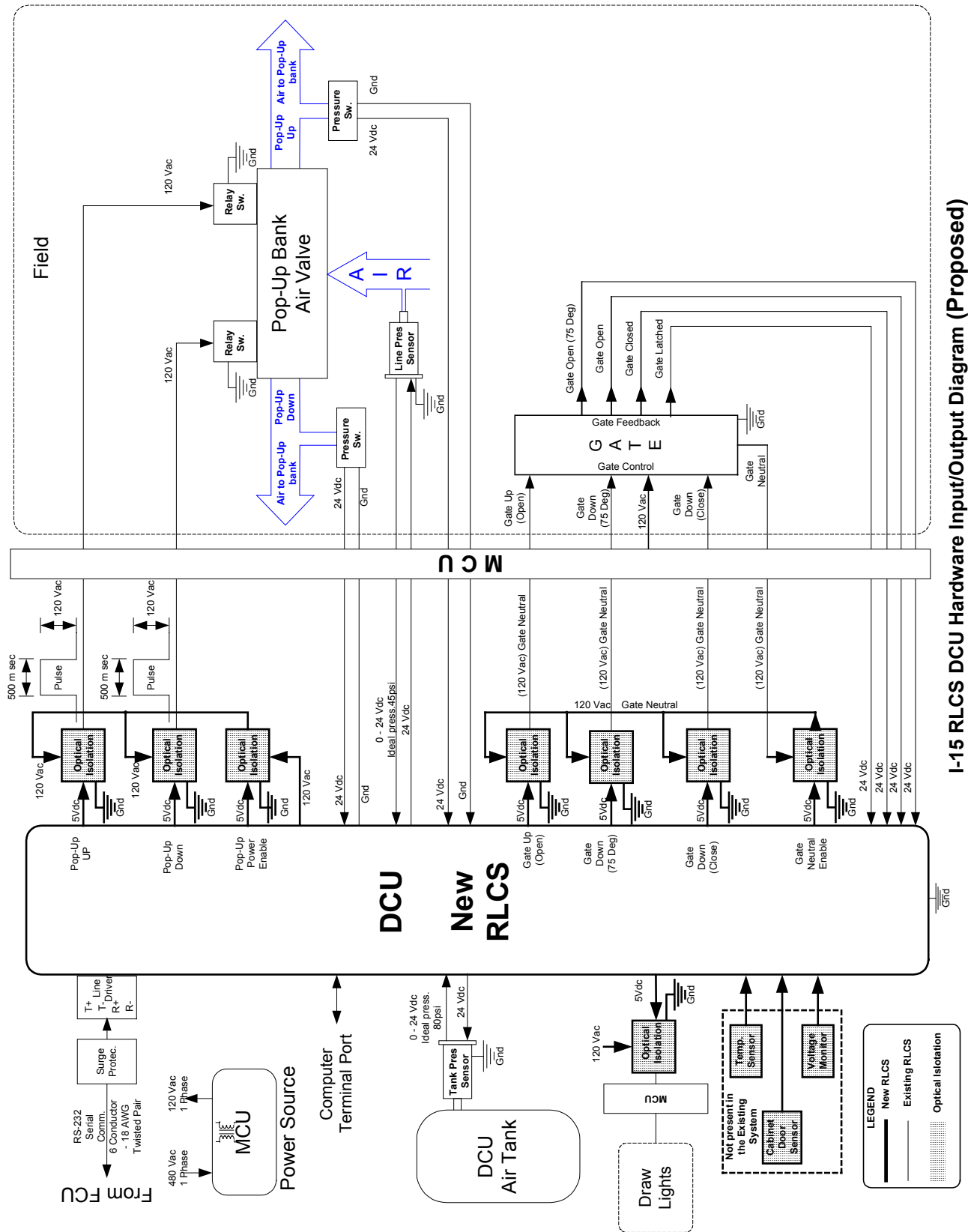
# Appendix D Existing and Proposed FCU and DCU Inputs/Outputs



I-15 RLCS FCU Hardware Input/Output Diagram (Existing)









## **Appendix E – Transportation Electrical Equipment Specification (TEES) for the 2070 Controller**

This document can be found at the Department of Transportation web site at

<http://www.dot.ca.gov/hq/traffops/electsys/2070/2070a.htm>

## Appendix F – Initial System Configuration Data for Operational Sequences and System Modes

This section describes the RLCS operational requirements which are critical to designing a safe control system. This section also lays down operational rules, which the software must implement and adhere to.

### F.1 Open Entrances

RLCS facility entrances allow vehicles to enter from the adjacent main lanes of I-15 or SR-163. Each entrance serves only one direction of travel (either Northbound, or Southbound). Each entrance is, as necessary, opened in order to allow access to the facility, or closed in order to either close the facility, or open it in the opposing direction.

RLCS facility exits, used by vehicles to exit the facility, are always open and have no control devices associated with them.

In the direction of travel on the freeway, RLCS facility entrance closure devices consist of:

1. Changeable Message Signs (CMS)
2. Entrance Longitudinal Pop-ups
3. Entrance Transverse Pop-ups
4. Barrier Gates
5. Wrong Way Transverse Pop-ups
6. Wrong Way Longitudinal Pop-ups

Operation of each closure device will entail one or more commands from its associated control unit. Each command, which operates a single closure device, shall have a specific 'response time window' defined for successful command completion. In addition, each compound command, which includes more than one 'single device' command, shall have a specific 'response time window' defined for successful command completion of the compound command.

The control system must not attempt to open any entrance closure device, if the status of any opposite direction entrance closure device is 'unknown' or open'.

Steps within a command, or command group, shall be executed sequentially, whether the individual commands in a group, will be executed by one (1) control unit, or by more than one control unit.

### F.2 Roadway Closure Device Status

The current status of all entrance closure devices in the system must be maintained at each control unit. The state of the closure devices shall be updated in all control units. The update frequency shall be higher during the opening and closing periods. Closure device sensors shall be monitored continuously by their local control unit. The status should be forwarded immediately to all other control units in the system.

### F.3 Opening Sequences

Opening sequences must open Entrance devices in the following order:

1. Barrier Gate
2. Wrong Way Transverse Pop-ups  
If more than one bank, banks are opened in the direction from the freeway toward the reversible lanes.
3. Wrong Way Longitudinal Pop-ups

Pop-up banks are opened beginning at the entrance ramp nose at the reversible lanes, and proceeding toward the edge of shoulder.

4. Entrance Transverse Pop-ups

If more than one bank, the banks are opened in the direction from the reversible lanes toward the freeway.

5. Entrance Longitudinal Pop-ups

Pop-up banks are opened downstream (entrance ramp nose at the freeway) to upstream (edge of shoulder).

6. CMS

CMS messages will be changed from a 'Closed' message, to an 'Open' message beginning with the furthest downstream sign (sign closest to the reversible lane), and proceeding upstream (away from the reversible lanes) as message change confirmations are received from each sign.

At any point in an opening sequence, the sequence shall be halted if:

- A device fails to report completion of the current sequence step within the response time window allotted for the step, or
- The status of a closure device for the opposite direction of travel changes to 'unknown' or 'open', or
- The status of a closure device, which was previously opened at the current entrance, changes to 'unknown' or 'closed'.

## F.4 Closing Sequences

Closing sequences must close Entrance devices in the following order:

1. CMS

CMS messages will be changed from "Open" to "Closed" beginning with the farthest upstream sign (furthest away from the entrance) and proceeding, in order, downstream (towards the entrance). The system shall provide for a specific delay between the message change on each sign and the message change on the next downstream sign. The delay for each sign pair shall equal the time to travel between the two signs at a system specified speed.

2. Entrance Longitudinal Pop-ups

Entrance Longitudinal Pop-ups must be closed in the direction of adjacent freeway traffic (beginning at the shoulder edge and proceeding toward the entrance ramp nose).

3. Entrance Transverse Pop-ups

If more than one bank, Entrance Transverse Pop-ups will be closed in the direction from the freeway toward the reversible lanes.

4. Wrong Way Longitudinal Pop-ups

Wrong Way Longitudinal Pop-ups will be closed beginning at the shoulder edge, and progressing toward the ramp nose, next to the reversible lanes.

5. Wrong Way Transverse Pop-ups

If more than one bank, Wrong Way Transverse Pop-ups will be closed in the direction from the reversible lanes toward the freeway.

6. Barrier Gate

At any point in a closing sequence, the sequence shall be halted if either:

3. A device fails to report completion of the current sequence step within the response time window allotted for the step, or
4. The status for a closure device, which was previously closed at the current entrance, changes to 'unknown' or 'open'.

## F.5 'Halted' Opening and Closing Sequences

A 'halted' opening or closing sequence shall cause the system to enter a 'hold' state for a system specified time. If the offending device status can be corrected within the specified time period, the operator shall be able to enter a 'resume' command in order for the system to attempt to complete the original opening/closing sequence.

## F.6 Multiple Entrances

If multiple entrances exist on the reversible lanes in the direction of travel being opened, the specific order in which those entrances are opened presents no 'wrong way' safety issues. Likewise, if multiple entrances exist on the reversible lanes in the direction of travel being closed, the specific order in which those entrances are closed presents no 'wrong way' safety issues.

## F.7 Safety Screening of Commands

Safety screening shall be done to determine if execution of a proposed command, if successful, would produce a valid reversible lanes configuration. If the screened command, including any subordinate commands would result in an unacceptable reversible lanes configuration, the screening check is considered to have failed.

In the following section, the term 'device command' shall be understood to include any simple command, command group, or macro, which may, if executed, change the state of one or more entrance devices.

In the case of device command groups (macros, compound commands, etc.) any screening requirement shall be applied to the command group, and to each device command within the group, prior to execution.

Each instance of safety screening shall utilize system configuration data that is no more than 3 seconds old.

Safety screening of device commands shall be multi-layered.

1. Safety screening shall be applied to all device commands at the originating control unit, and at all subordinate control units to which the device command or any of its subordinate device commands may be forwarded.
2. Safety screening shall always be applied to any device command, or command step, by any control unit which directly operates the target entrance closure device(s), just prior to actual command execution.

An opening or closing sequence shall be halted, with an appropriate error response to the system operator, if, at any sequence step, command safety screening fails.

## F.8 Control System Integrity

### Control Unit Non-Volatile Memory

In each FCU and DCU in the system, the following items shall be replicated from the central database server and maintained in non-volatile, non-removable memory:

- Login Tables
- Closure Device Timing Parameters
- Air Calibration Factors
- Reversible Lanes Configuration Table(s)
- Reversible Lanes Operating Logic, Control Sequences, and Rule Sets



## **F.9 Control System Integrity Verification**

The system will employ a one-way hash function as an aid to encrypting and maintaining the integrity of the data and software in the field. The hash value returned by the function will be at least 128 bits in length. The MD5 algorithm is acceptable for this purpose. This algorithm will reside in all the controllers and the application server.

At each time, one or more of the above item types, listed under 'Control Unit Non-Volatile Memory', is created or modified, a UTC date/time stamp will be appended to the code (or table). The appending of the time stamp will be the last step in the process which builds the time stamped code/data section.

The system will also, for each control unit in the system, produce a table of the returned 'one-way hash function' (Message Digest) values, of each of the 'Control Unit Non-Volatile Memory' items. The returned 'Message Digest' values will be stored as hexadecimal characters. The appropriate 'Message Digest' table will be maintained in non-volatile memory in each system control unit.

The system will provide for periodic verification that current, recomputed 'Message Digest' values, for each unit in the system, correspond with 'record' values computed by the development process. The periodic evaluation will occur at least once a day. The 'Message Digest' value verification results will be recorded in the system log. A verification failure will cause an alarm condition for the affected control unit. If the failure occurs in checking the non-volatile memory items, the system will prevent the affected unit from being used in control sequences.

The system will provide for 'Message Digest' verification requests for a given unit by operator command.

For system login purposes, the hash function will also be used to encrypt user passwords.

The system will provide for passphrase aging. Whether or not the system will require passphrase aging will be controllable by the System Administrator.

The system will provide for minimum username and passphrase lengths. The minimum length values will be controllable by the system administrator.



## F.10 Access and Safety Characteristics of the I-15 Reversible Roadway

The software must implement.

### Characteristics Bearing on Security

1. Isolation –  
The current state of the roadway may be transmitted from the RLCS to the external server data store via a network protected by a firewall or via a one-way outbound serial link. The Reversible Lane Control System does not accept or process any inputs from other systems.
2. Closure Device Status Circulation –  
The current state of each roadway closure device and device status change is circulated to all control units in the system, every 2 seconds.
3. Command Forwarding –  
Commands are only forwarded from superior units to inferior units. This prevents a lower level unit from changing the state of a device which is controlled by either a higher level unit, or by a peer unit.
4. Command Processing –  
Device control units utilize device feedback, coupled with strict response time windows for device opening and closing commands.
5. Uncertain status –  
Unknown, or improper closure device status anywhere in the system, will immediately terminate a 'device opening' command. Improper device status 'may' terminate a device closing command, or sequence.

### Physical Access/Control Table

Access Point	Control Ability
TMC	All RLCS Closure Devices
FCU South	All RLCS Closure Devices
DCU 1	NB 15 Entrance Wrong Way Devices and Gate
DCU 2	NB 163 Entrance Devices and Gate
DCU 3	NB 163 Wrong Way Devices
FCU North	All RLCS Closure Devices
DCU 4	SB 15 Wrong Way Devices
DCU 5	SB 15 Entrance Devices and Gate
CMS 1-12	Individual CMS Control



### F.11 Normal Operations (Operator is logged on)

The system must allow the following scheduled operations at a minimum during 'normal' operational mode:

Sequence #1: Goal State: Open South Bound (AM) / Initial State: Closed (PM)

AM Opening South Bound at 5:20 AM. (Initially Gate 5 at Loc. 5 is OPEN)

Step #	Operation	Device	Location
	Status check by Operator	All	All
1	CLOSE	Gate 1	Loc. 1 South End 15
2	CLOSE	Gate 2	Loc. 2 South End 163
3	OPEN	WW-Pop-ups	Loc. 4
4	OPEN	Draw Light	North End 15
5	OPEN	EN-Pop-ups	Loc. 5
6	OPEN	CMS 9-12	North End 15

Sequence #2: Goal State: Closed (AM) / Initial State: Open South Bound (AM)

AM Closing South Bound at 11:00 AM

Step #	Operation	Device	Location
	Status check by Operator	All	All
1	CLOSE	CMS 9-12	North End 15
2	CLOSE	EN-Pop-ups	North End 15
3	CLOSE	WW-Pop-ups	North End 15
4	OPEN	Gate 1	Loc. 1 South End 15
5	OPEN	Gate 2	Loc. 2 South End 163

Sequence #3: Goal State: Open North Bound (PM) / Initial State: Closed (AM)

PM Opening North Bound at 11:15 AM

Step #	Status	Device	Location
	Status check by Operator	All	All
1	CLOSE	Gate 5	Loc. 5 North End 15
2	OPEN	WW Lights	Loc. 4 North End 15
3	OPEN	WW-Pop-ups	South End 163
4	OPEN	WW-Pop-ups	South End 15
5	OPEN	EN-Pop-ups	South End 15
6	OPEN	CMS 1-4	South End 15
7	OPEN	EN-Pop-ups	South End 163
8	OPEN	CMS 5-8	South End 163

Sequence #4: Goal State: Closed (PM) / Initial State: Open North Bound (PM)

PM Closing of RLCS at 7:00 PM.

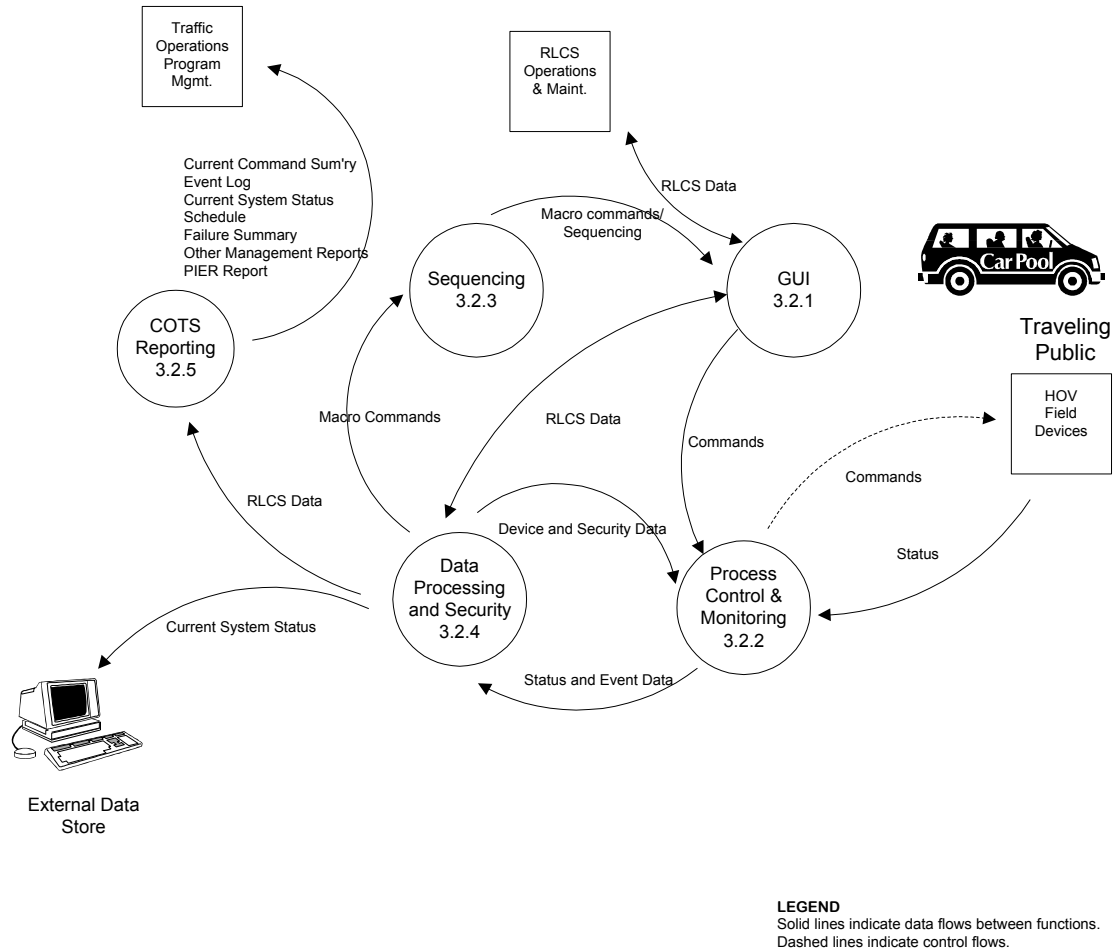
Step #	Status	Device	Location
	Status check by Operator	All	All
1	CLOSE	CMS 1-4	South End 15
2	CLOSE	EN-Pop-ups	South End 15
3	CLOSE	WW-Pop-ups	South End 15
4	CLOSE	CMS 5-8	South End 163
5	CLOSE	EN-Pop-ups	South End 163
6	CLOSE	WW-Pop-ups	South End 163
7	CLOSE	WW-Lights	North End 15
8	OPEN	Gate 5	North End 15



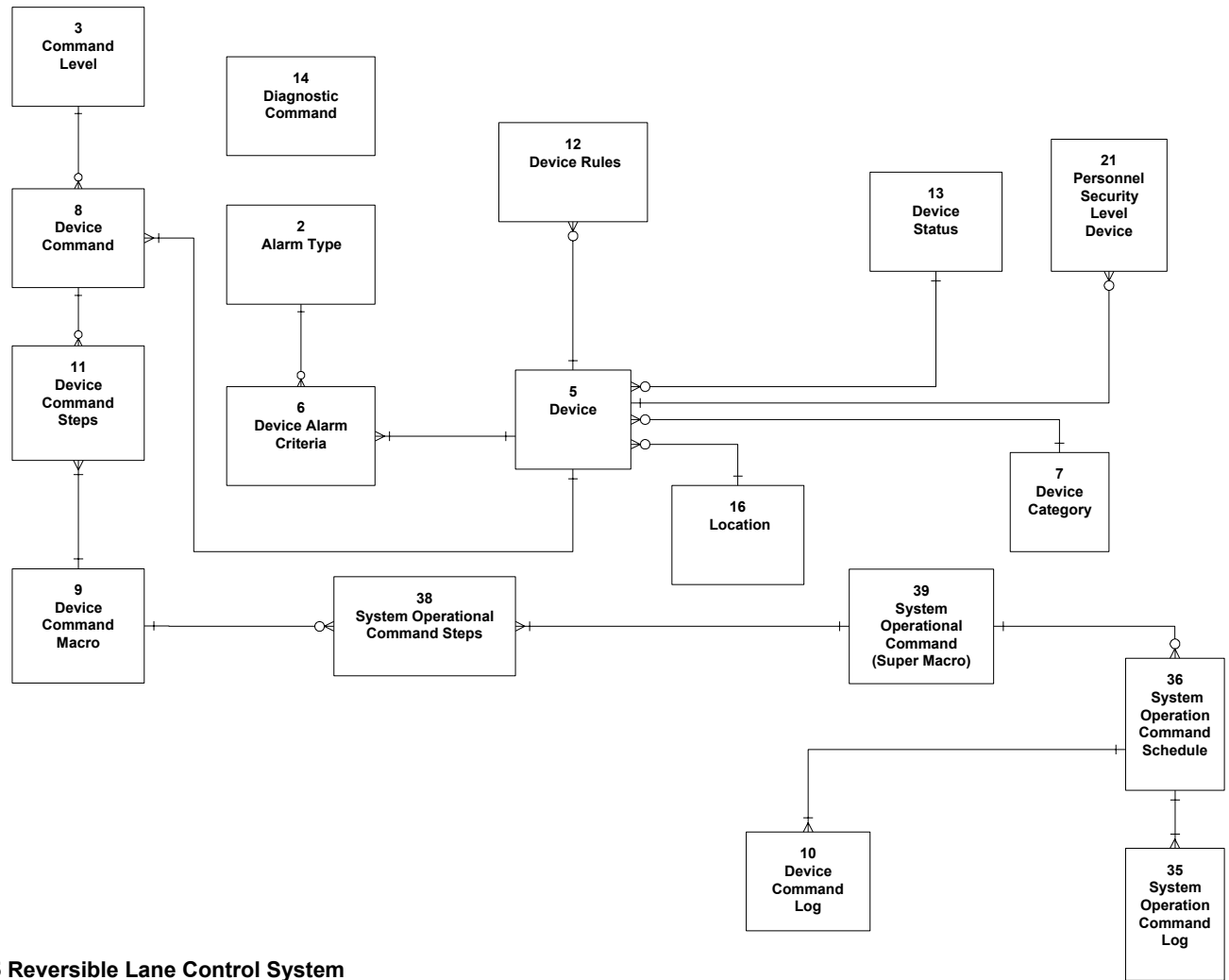
## **F.12 Unattended Operations (No operator is logged on)**

When no operator is logged on to the system, the status of all devices will continue to be monitored and displayed. If a scheduled operational sequence requires an operator to be logged on to confirm each step of the operation, an audible alarm will sound to alert the operator to log on to the system.

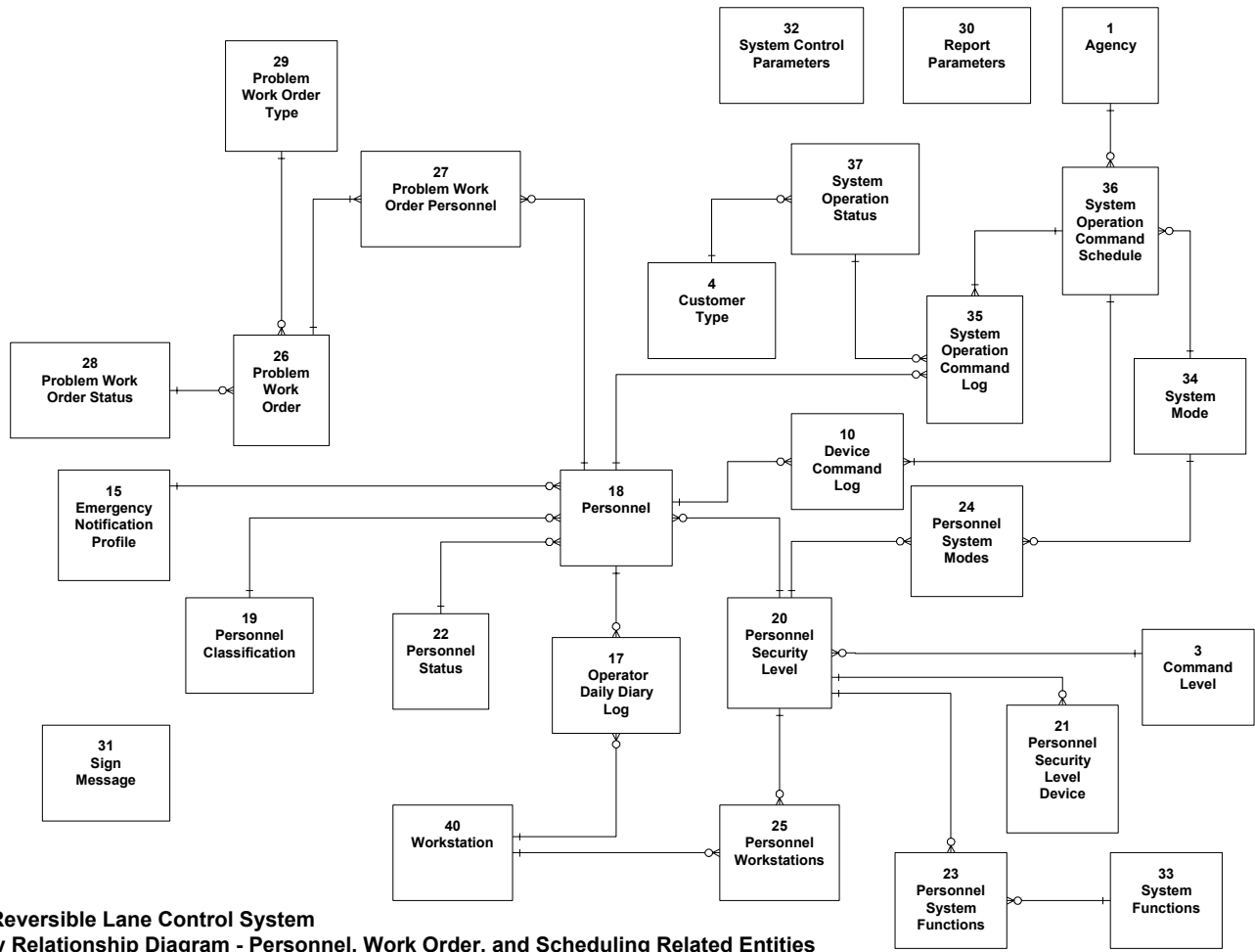
## Appendix G – Data Flow Diagrams and Data Model for RLCS Application Software



**I-15 Reversible Lane Control System  
Level 1 - Data Flow**



**I-15 Reversible Lane Control System  
Entity Relationship Diagram - Device and Command Related Entities**





#	Entity Name	Relationships
1	Agency	<ul style="list-style-type: none"><li>Each Agency may be referenced in one or more System Operation Schedules</li></ul>
2	Alarm Type	<ul style="list-style-type: none"><li>Each Alarm Type may be referenced in one or more Device Alarm Criteria</li></ul>
3	Command Level	<ul style="list-style-type: none"><li>Each Command Level may be referenced in one or more Device Commands</li></ul>
4	Customer Type	<ul style="list-style-type: none"><li>Each Customer Type may be referenced in one or more System Operation Statuses</li></ul>
5	Device	<ul style="list-style-type: none"><li>Each Device has one Device Type</li><li>Each Device has one Device Status</li><li>Each Device has one Location</li><li>Each Device may have one or more Device Rules</li><li>Each Device has one or more Alarm Criteria</li><li>Each Device has one or more Device Commands</li><li>Each Device may be referenced in one or more Personnel Security Level Device</li></ul>
6	Device Alarm Criteria	<ul style="list-style-type: none"><li>Each Device Alarm Criteria is for one Device</li><li>Each Device Alarm Criteria references one Alarm Type</li></ul>
7	Device Category	<ul style="list-style-type: none"><li>Each Device Category describes one or more Devices</li></ul>
8	Device Command	<ul style="list-style-type: none"><li>Each Device Command refers to one Device</li><li>Each Device Command may be referenced in one or more Device Command Steps</li><li>Each Device Command is described by one Command Level</li></ul>
9	Device Command Macro	<ul style="list-style-type: none"><li>Each Device Command Macro has one or more Device Command Steps.</li><li>Each Device Command Macro may be referenced in one or more System Operational Command Steps</li></ul>
10	Device Command Log	<ul style="list-style-type: none"><li>Each Device Command Log entry is generated by one System Operation Command Schedule</li></ul>
11	Device Command Steps	<ul style="list-style-type: none"><li>Each Device Command Step refers to one Device Command\</li><li>Each Device Command Step refers to one Device Command Macro</li></ul>
12	Device Rules	<ul style="list-style-type: none"><li>Each Device Rule references one Device</li></ul>
13	Device Status	<ul style="list-style-type: none"><li>Each Device Status may describe one or more Devices.</li></ul>
14	Diagnostic Command	<ul style="list-style-type: none"><li>Each Diagnostic Command has no associations or relationships with any other entity.</li></ul>
15	Emergency Notification Profile	<ul style="list-style-type: none"><li>Each Emergency Notification Profile may describe one or more Personnel</li></ul>
16	Location	<ul style="list-style-type: none"><li>Each Location may describe one or more Devices</li></ul>
17	Operator Daily Diary Log	<ul style="list-style-type: none"><li>Each Operator Daily Diary Log entry is for one Personnel</li><li>Each Operator Daily Diary Log entry references one Workstation</li></ul>
18	Personnel	<ul style="list-style-type: none"><li>Each Personnel has one Personnel Security Level</li><li>Each Personnel has one Personnel Status</li><li>Each Personnel has one Emergency Notification Profile</li><li>Each Personnel has one Personnel Classification</li><li>Each Personnel may be referenced in one or more Operator Daily Diary Log entries</li><li>Each Personnel may be referenced in one or more System Operation Command Logs</li><li>Each Personnel may be referenced in one ore more Device Command Logs</li></ul>



#	Entity Name	Relationships
		<ul style="list-style-type: none"><li>Each Personnel may be referenced in one or more Problem Work Order Personnel</li></ul>
19	Personnel Classification	<ul style="list-style-type: none"><li>Each Personnel Classification may describe one or more Personnel</li></ul>
20	Personnel Security Level	<ul style="list-style-type: none"><li>Each Personnel Security Level may describe one or more Personnel</li><li>Each Personnel Security Level may be authorized for one or more Personnel Workstations</li><li>Each Personnel Security Level may be referenced by one or more Personnel Security Level Devices.</li><li>Each Personnel Security Level may be authorized for one or more Personnel System Functions</li><li>Each Personnel Security Level may be authorized for one or more Personnel System Modes</li><li>Each Personnel Security Level has one Command Level</li></ul>
21	Personnel Security Level Device	<ul style="list-style-type: none"><li>Each Personnel Security Level Device references one Device and one Personnel Security Level</li></ul>
22	Personnel Status	<ul style="list-style-type: none"><li>Each Personnel Status may describe one or more Personnel</li></ul>
23	Personnel System Functions	<ul style="list-style-type: none"><li>Each Personnel System Function references one Personnel Security Level and one System Function</li></ul>
24	Personnel System Modes	<ul style="list-style-type: none"><li>Each Personnel System Mode references one Personnel Security Level and one System Mode</li></ul>
25	Personnel Workstations	<ul style="list-style-type: none"><li>Each Personnel Workstation references one Personnel Security Level</li></ul>
26	Problem Work Order	<ul style="list-style-type: none"><li>Each Problem Work Order has one Problem Work Order Type</li><li>Each Problem Work Order has one Problem Work Order Status</li><li>Each Problem Work is referenced by one or more Problem Work Order Personnel</li></ul>
27	Problem Work Order Personnel	<ul style="list-style-type: none"><li>Each Problem Work Order Personnel associates all the Personnel associated with one Problem Work Order</li><li>Each Problem Work Order Personnel associates all the Problem Work Orders associated with one Personnel</li></ul>
28	Problem Work Order Status	<ul style="list-style-type: none"><li>Each Problem Work Order Status may describe one or more Problem Work Orders</li></ul>
29	Problem Work Order Type	<ul style="list-style-type: none"><li>Each Problem Work Order Type may describe one or more Problem Work Orders</li></ul>
30	Report Parameters	<ul style="list-style-type: none"><li>Each Report Parameter has no associations or relationships with any other entity</li></ul>
31	Sign Message	<ul style="list-style-type: none"><li>Each Sign Message has no associations or relationships with any other entity.</li></ul>
32	System Control Parameters	<ul style="list-style-type: none"><li>Each System Control Parameter has no associations or relationships with any other entity</li></ul>
33	System Functions	<ul style="list-style-type: none"><li>Each System Function may be referenced by one or more Personnel System Functions</li></ul>
34	System Mode	<ul style="list-style-type: none"><li>Each System Mode may be used for one or more System Operation Schedules</li><li>Each System Mode may be referenced by one or more Personnel System Modes</li></ul>
35	System Operation Command Log	<ul style="list-style-type: none"><li>Each System Operation Command Log entry is generated by one System Operation Command Schedule execution</li><li>Each System Operation Command Log entry references one Personnel</li></ul>



#	Entity Name	Relationships
36	System Operation Command Schedule	<ul style="list-style-type: none"><li>• Each System Operation Command Schedule item refers to one Agency</li><li>• Each System Operation Command Schedule item refers to one System Mode</li><li>• Each System Operation Command Schedule item creates one or more System Operation Command Log entries</li><li>• Each System Operation Command Schedule item creates one or more Device Command Log entries</li><li>• Each System Operation Command Schedule references one System Operational Command or Device Command Macro or Device Command.</li></ul>
37	System Operation Status	<ul style="list-style-type: none"><li>• Each System Operation Status may be associated with one or more System Operation Command Log entries</li></ul>
38	System Operational Command Steps	<ul style="list-style-type: none"><li>• Each System Operational Command Step associates one Device Command Macro with all its System Operational Commands</li><li>• Each System Operational Command Step associates one System Operational Command with all its Device Command Macros.</li></ul>
39	System Operational Command (Super Macro)	<ul style="list-style-type: none"><li>• Each System Operational Command (Super Macro) is composed of one or more System Operational Command Steps</li><li>• Each System Operational Command may be referenced by one or more System Operation Command Schedules</li></ul>
40	Workstations	<ul style="list-style-type: none"><li>• Each Workstation may be referenced by one or more Operator Daily Diary Log entries.</li><li>• Each Workstation may be referenced by one or more Personnel Workstations.</li></ul>



Appendix H – System Cut-over Diagrams for Existing and New I-15 RLCS

NOTE: ALL THE WORK IS THE PROPERTY OF CALTRANS AND WILL BE DONE BY STATE

